

The qualitative and time- dependent character of spatial relations in biomedical ontologies

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CLINICAL RESEARCH IN TEMPOROMANDIBULAR DISORDERS

TMD is a pain and disability disorder

current studies have significantly increased the size of the domain of analysis
to capture all relevant variables

EXAMPLES OF MEASURABLE VARIABLES

pain levels

functional capacity

gross mobility of the jaw

mobility of the TMJ

pressure-pain threshold of the TMJ

biopsychosocial factors contributing to TMD

more numbers ...



Isberg
3.12

CLINICAL RESEARCH IN TEMPOROMANDIBULAR DISORDERS

TMD is a pain and disability disorder

current studies have significantly increased the size of the domain of analysis to capture all relevant variables

problems:

- how to link **quantitative** measurements to **qualitative** symptoms/treatment choices
- how to represent TMJ characteristics in a computer-based system that is interoperable with other data collected in the studies

We need to go **beyond** numbers!

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We need **qualitative** information

TMJ DYNAMICS: NORMAL & ABNORMAL

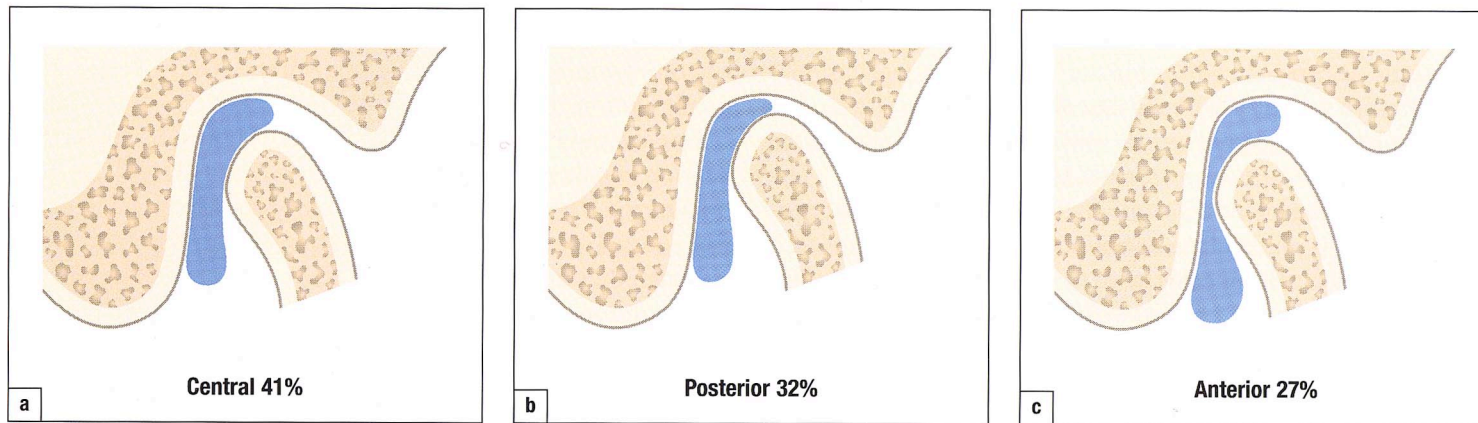


Figure 5.6. Condyle position in joints with normal disc position.

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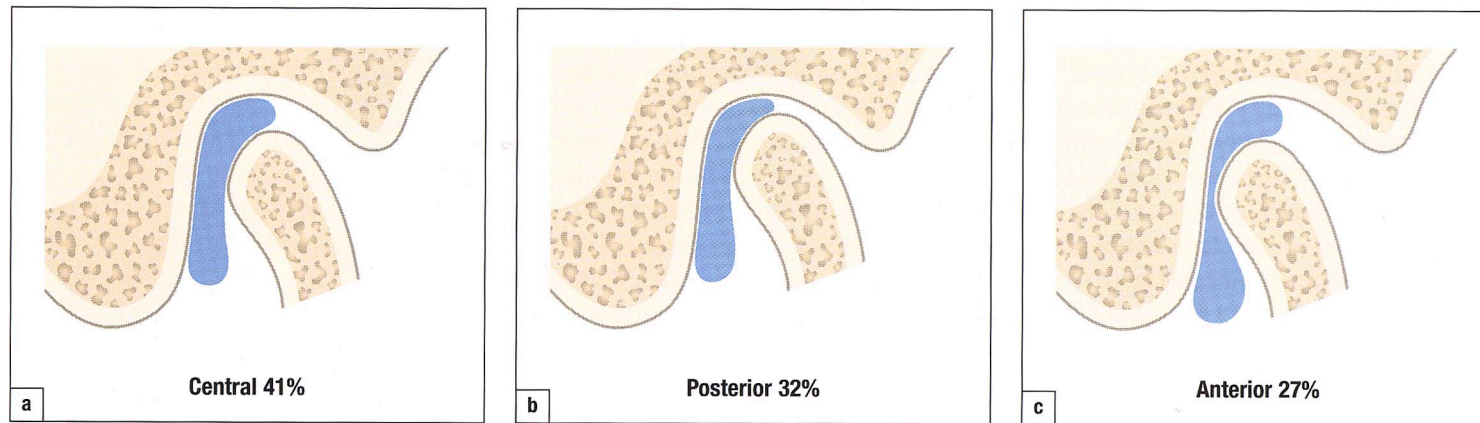
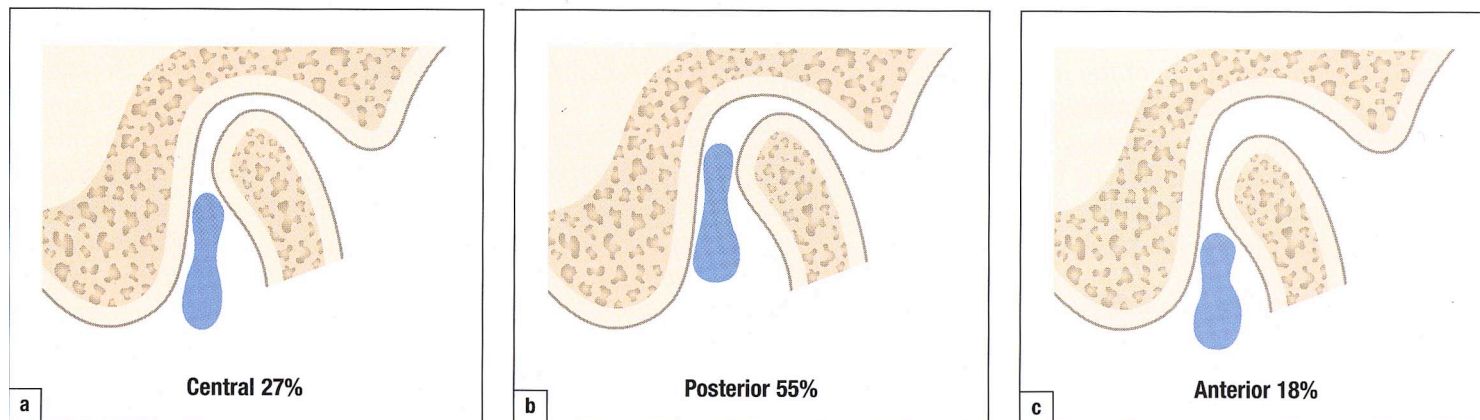


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- The **size** of those parts must be within certain limits (qualitative size and distance measures)

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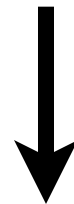


build **qualitative representations** of
canonical anatomy

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take advantage of research in qualitative
representation and reasoning in AI

How to build qualitative representations of canonical anatomical structures ?

1. Identify the major parts of the TMJ
2. Establish the connectedness, attachment, and adjacency relations among the various parts
3. Establish the qualitative order relations using landmarks as frames of reference
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Major parts of the TMJ

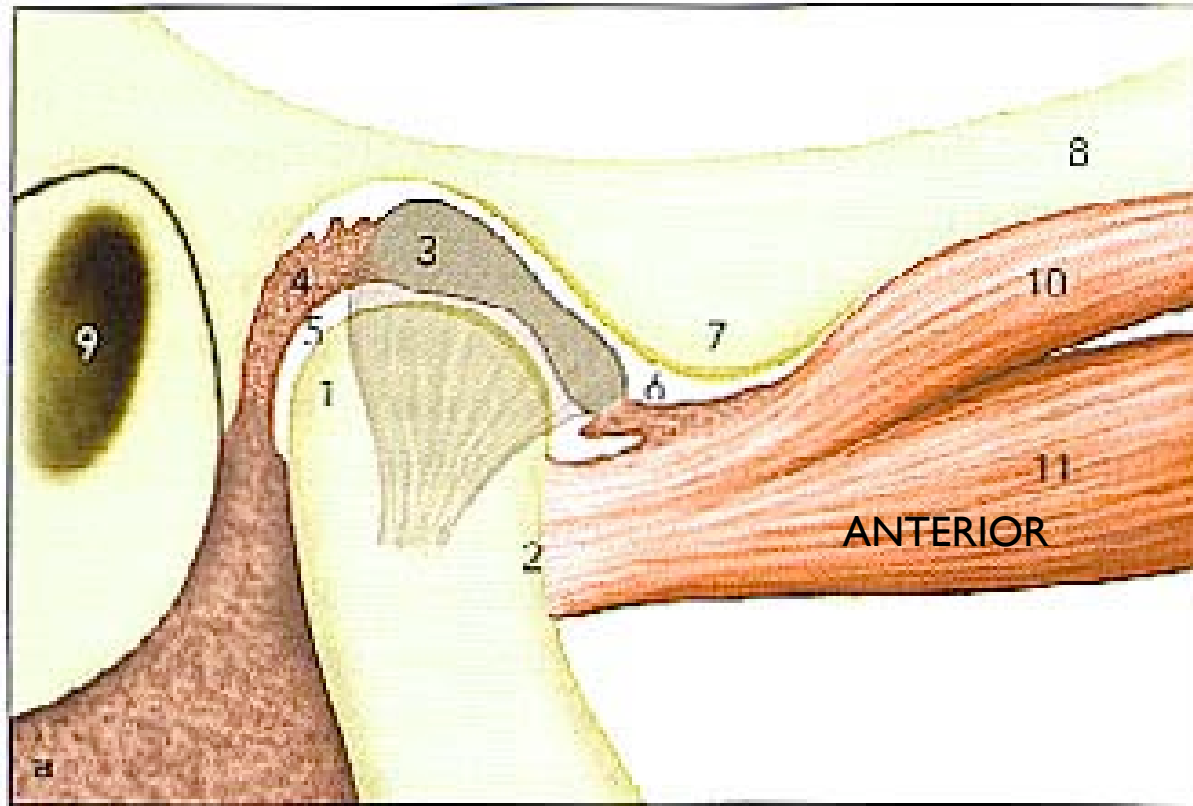
material parts

rigid parts

non-rigid parts

cavities

material parts



TMDs: An Evidence Based-Approach to Diagnosis and Treatment. (2006)
Eds: D. M. Laskin, C. S. Greene, W. L. Hylander. Quintessence Books,
Chicago. (temporal bone, head of condyle, articular disc, posterior
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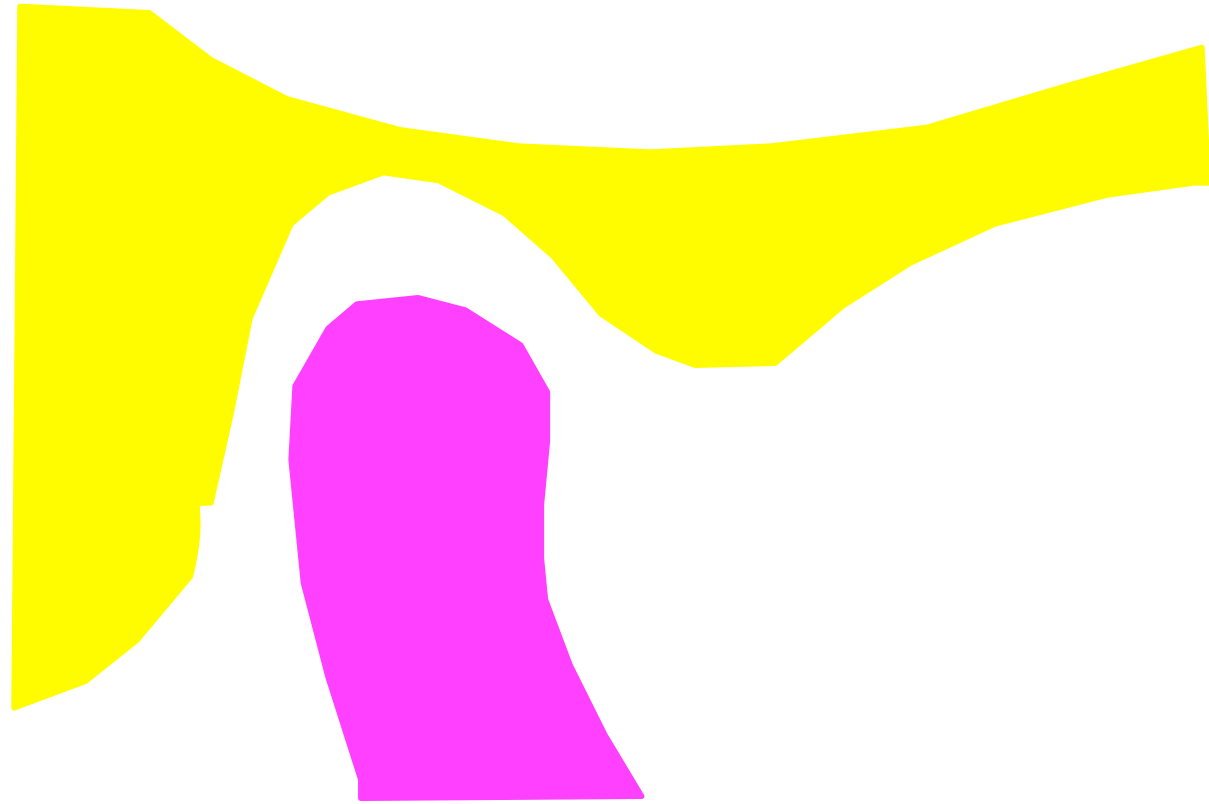
material parts



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Rigid material parts

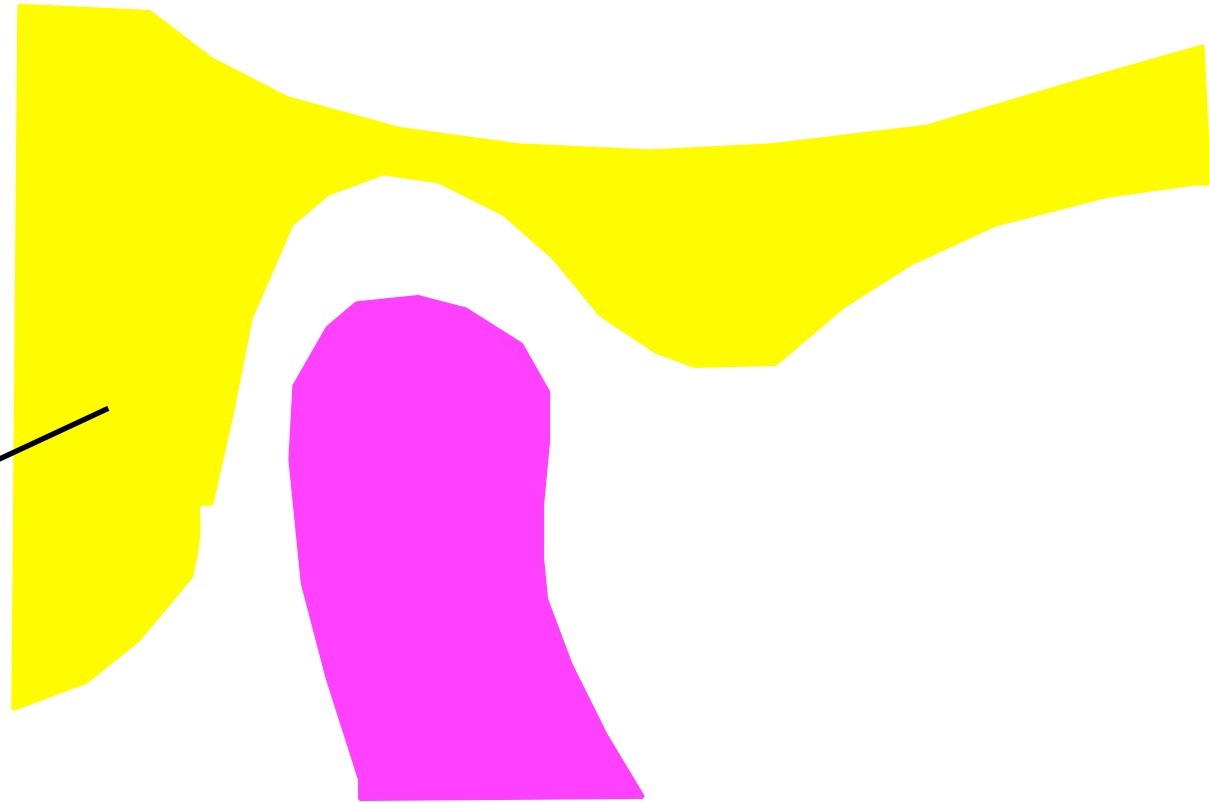
parts that do not
change shape
(bones)



Rigid material parts

parts that do not
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fixed

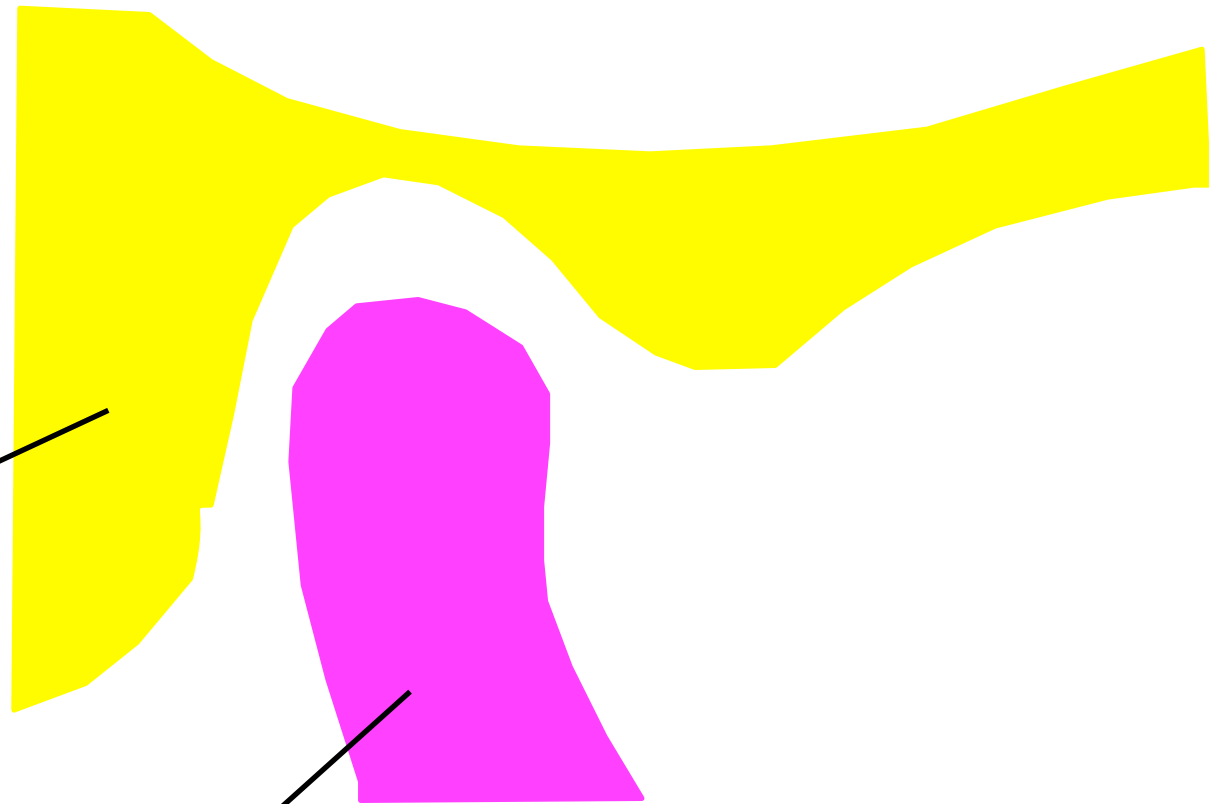


Rigid material parts

parts that do not
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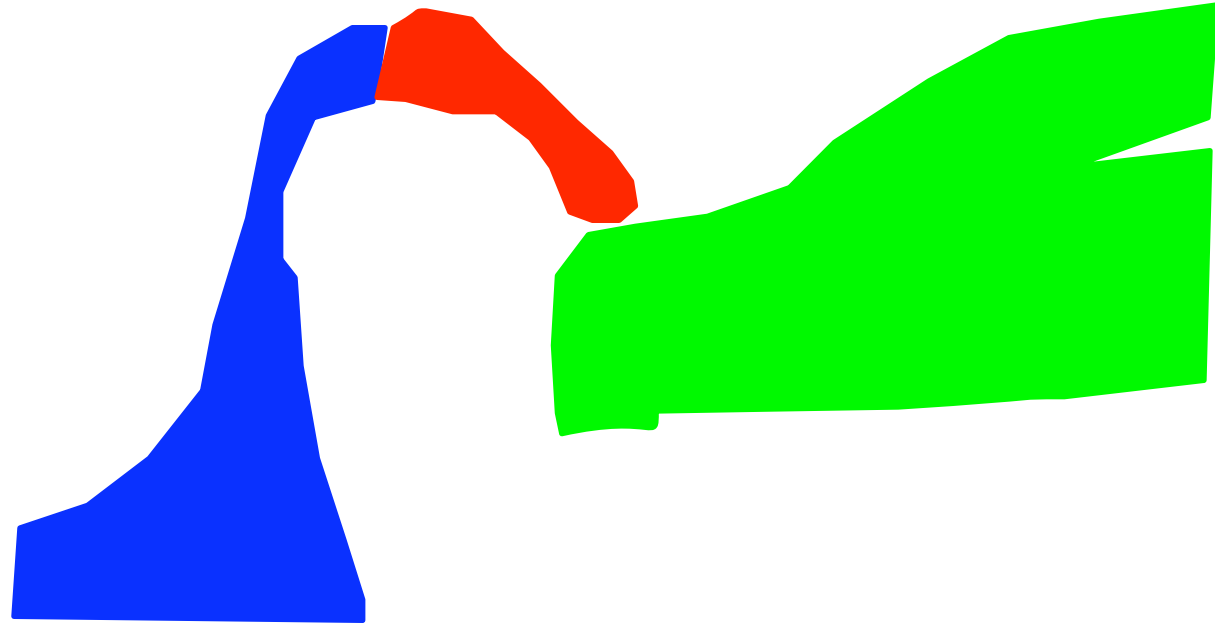
movable



Non-rigid material parts

parts that do change shape

but the topology does not change: the connected parts remain connected

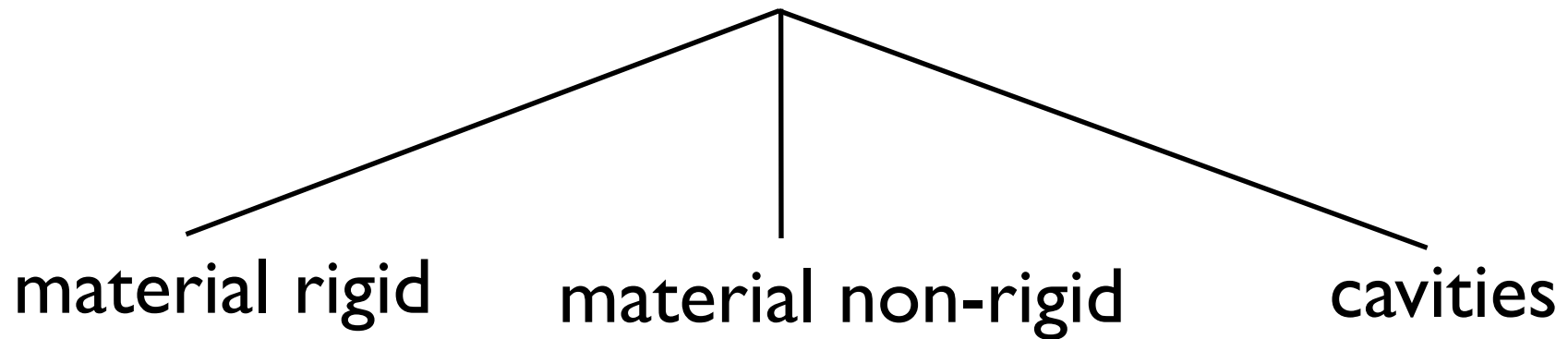


Cavities

filled with liquid:
synovial fluid in
the case of the
TMJ



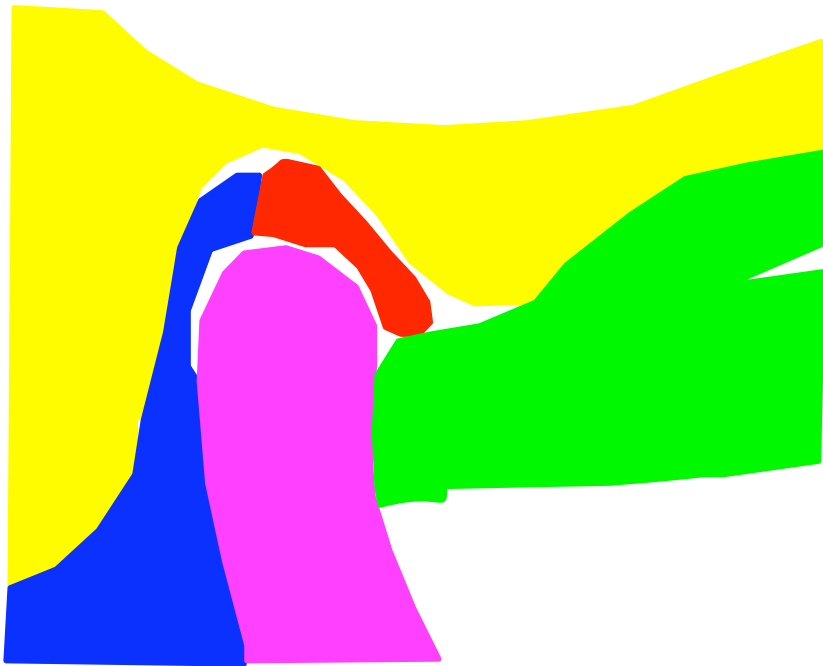
Three kinds of entities (parts) in the TMJ



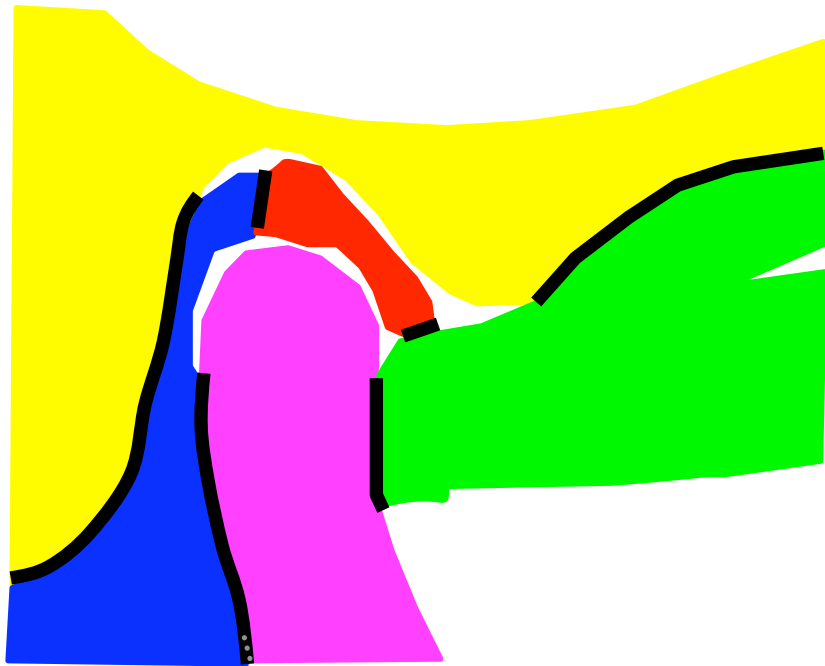
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Attachment Relations

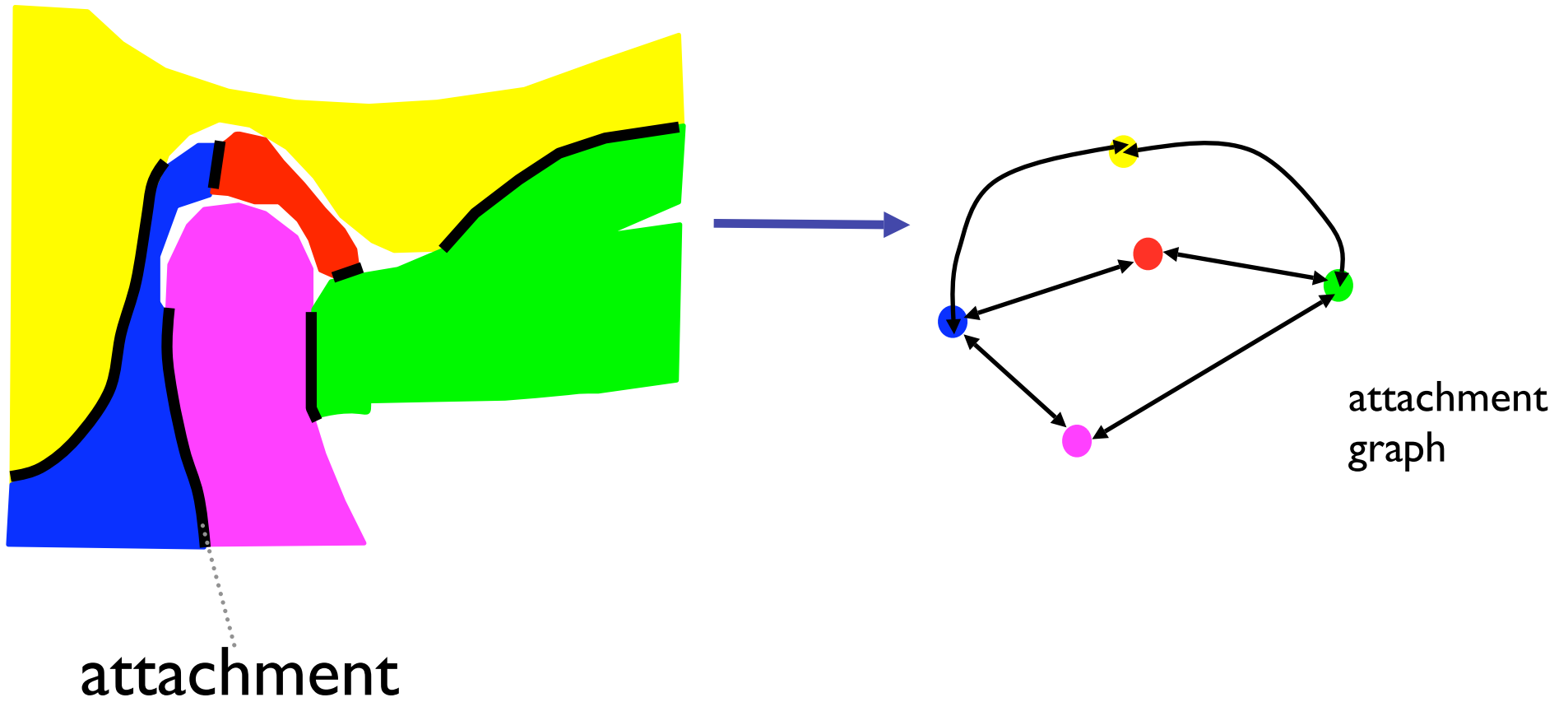


Attachment Relations

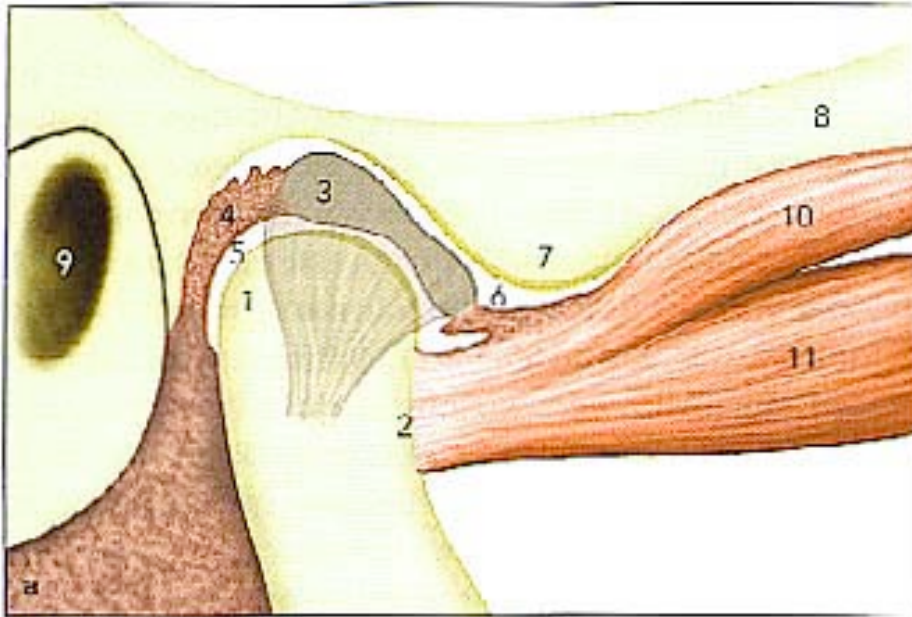


attachment

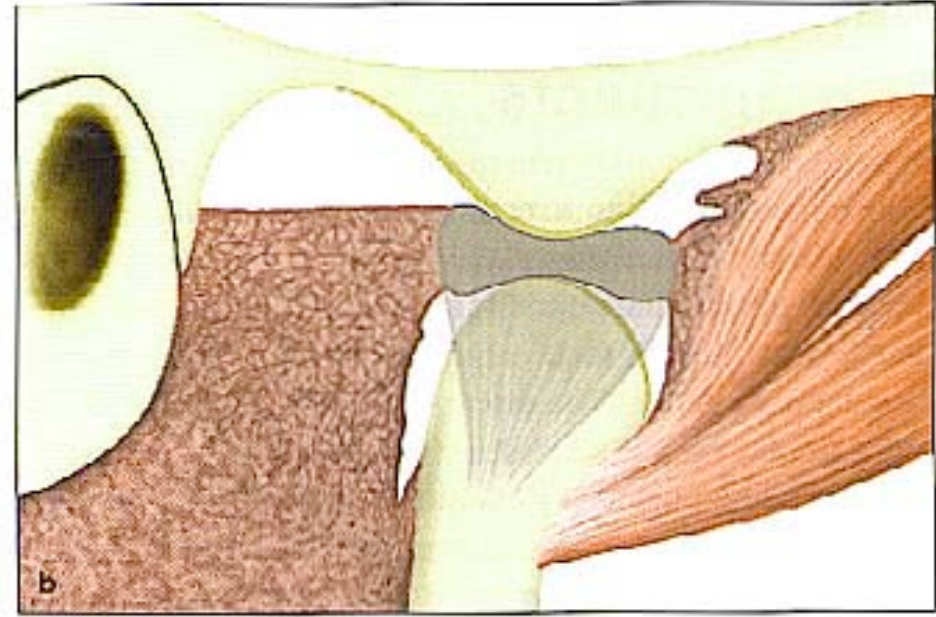
Attachment Relations



closed and opened positions



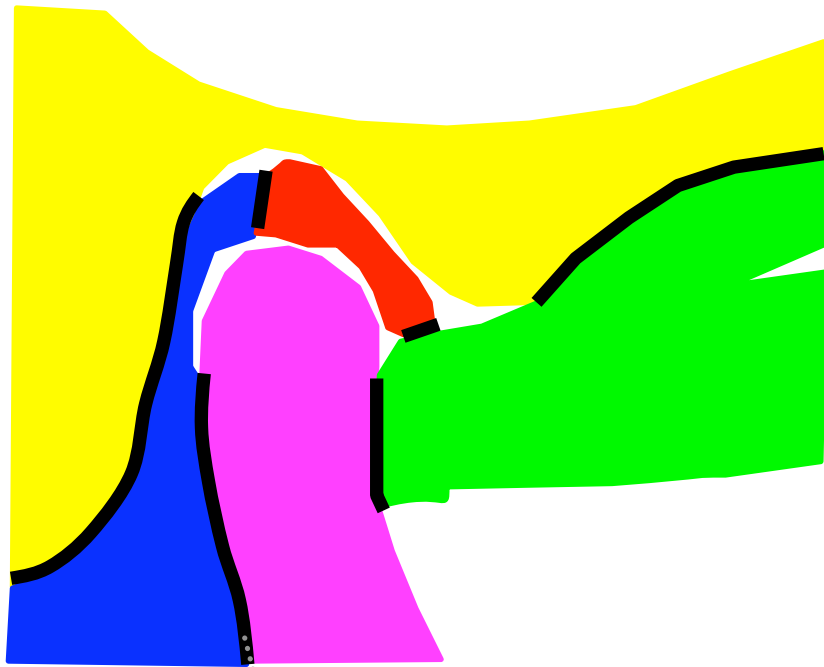
jaw closed



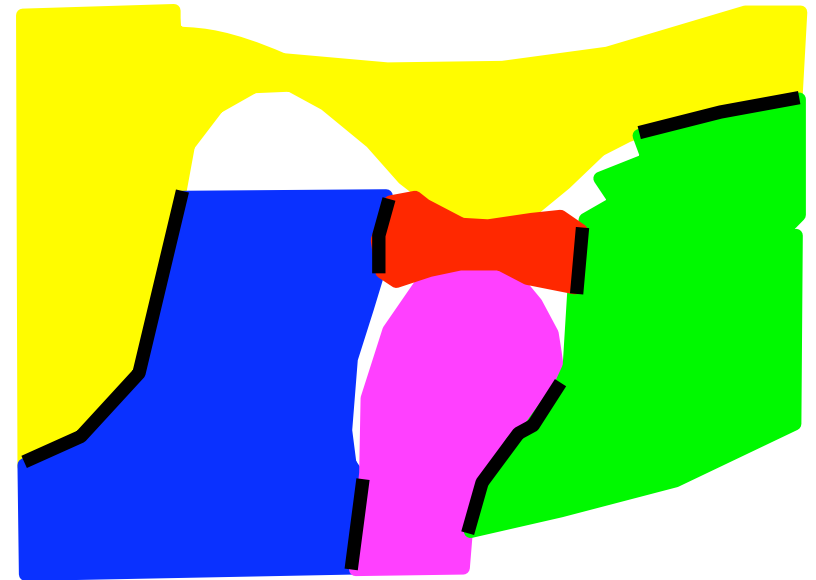
jaw opened

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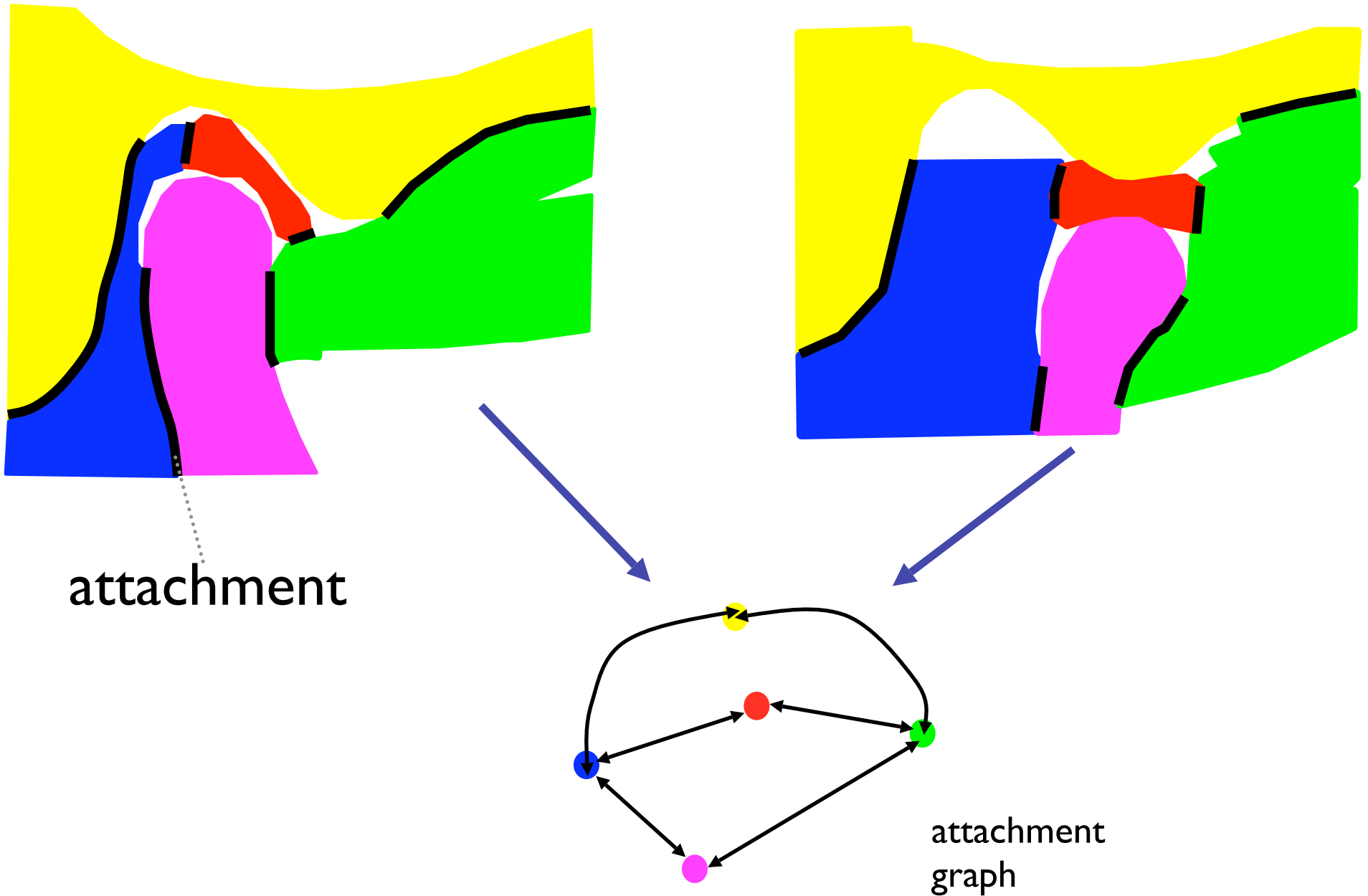
Attachment relations remains invariant in the opened and closed positions



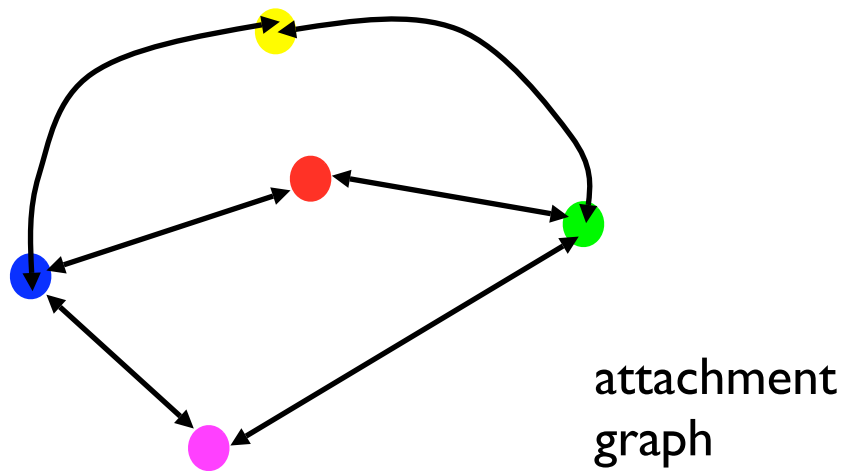
attachment



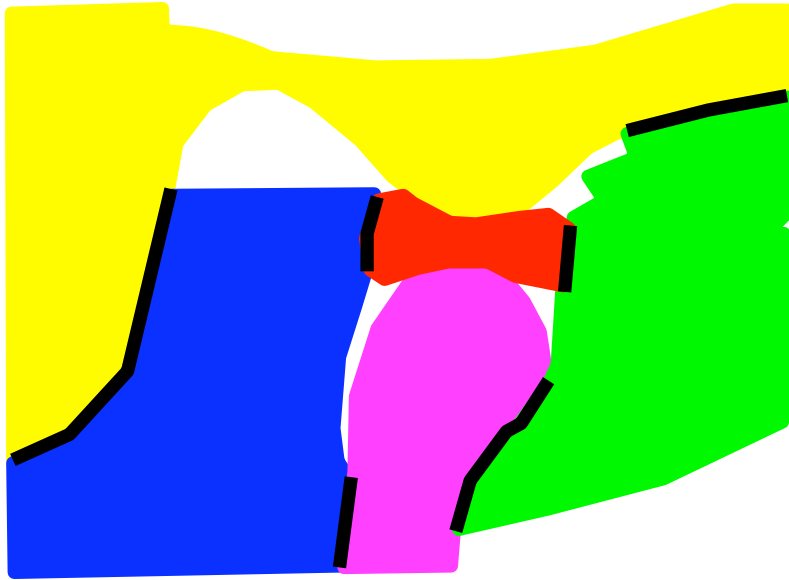
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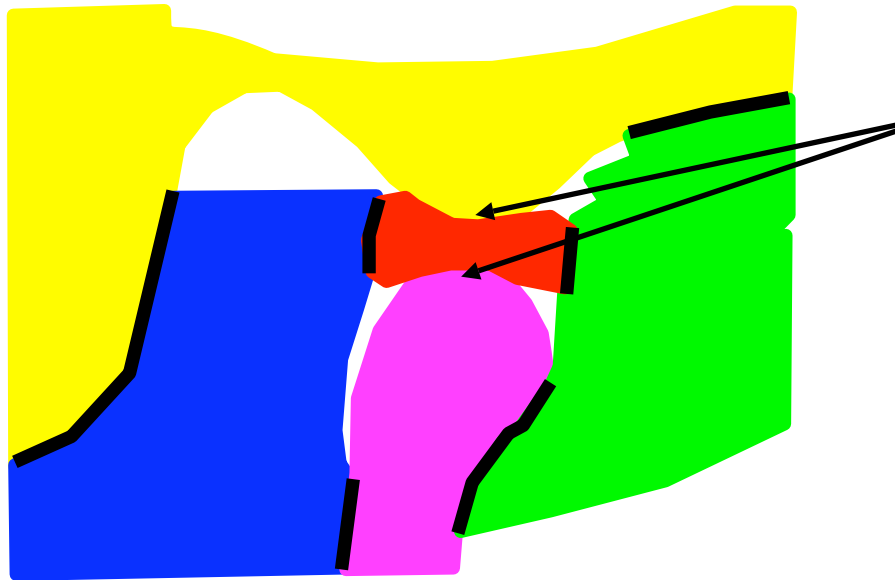
Every TMJ can be represented by this attachment graph



adjacency relations

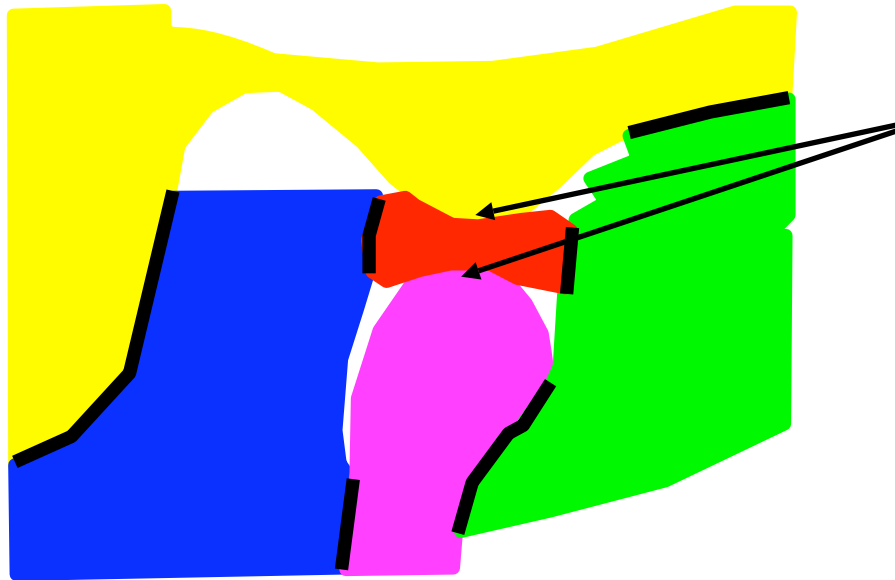


adjacency relations

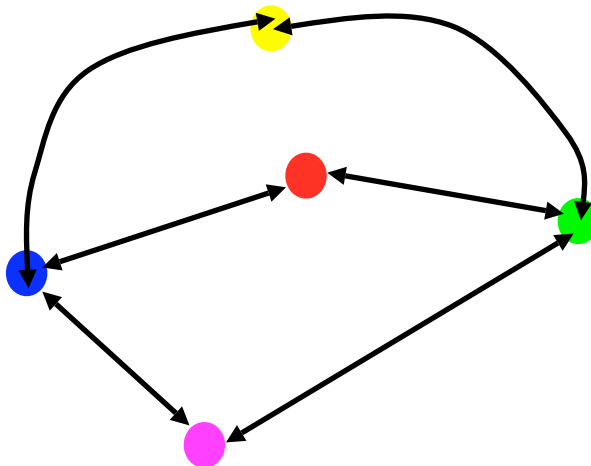


No attachment
only (temporary)
adjacency

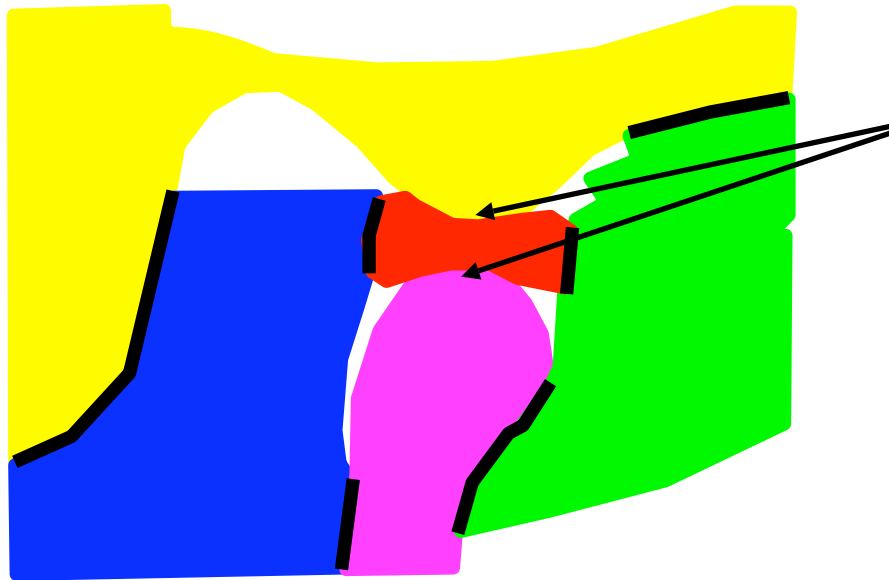
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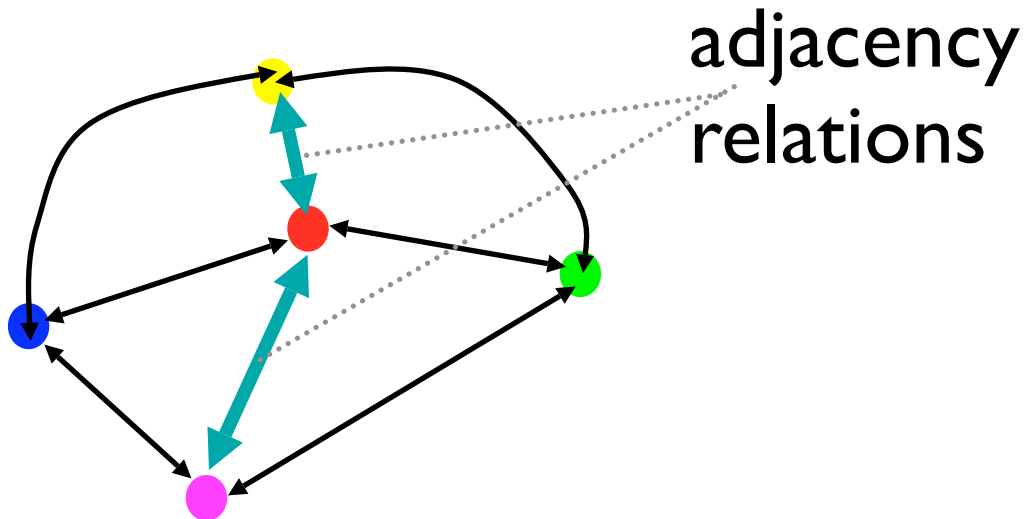
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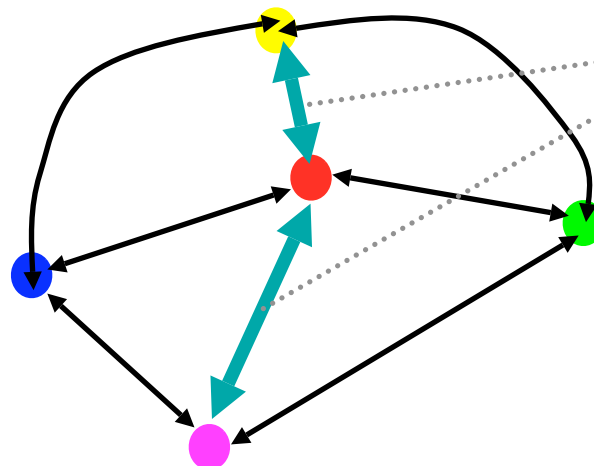


adjacency
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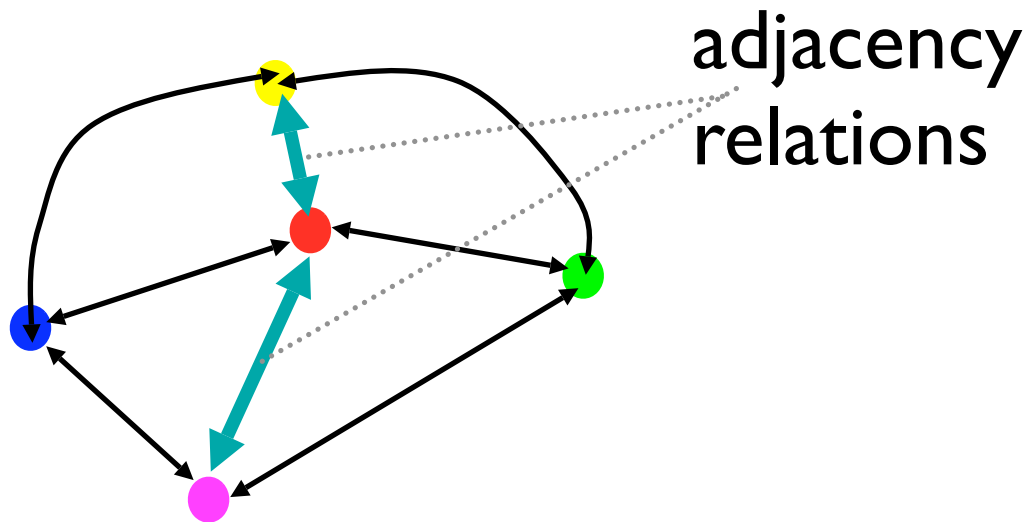
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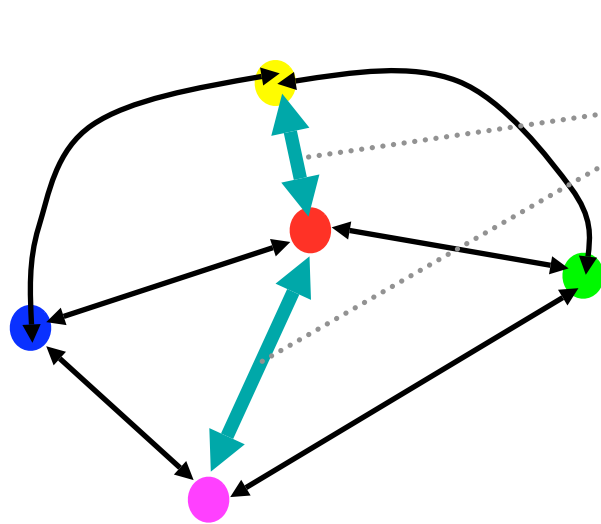
adjacency
relations

attachment
adjacency
graph

adjacency



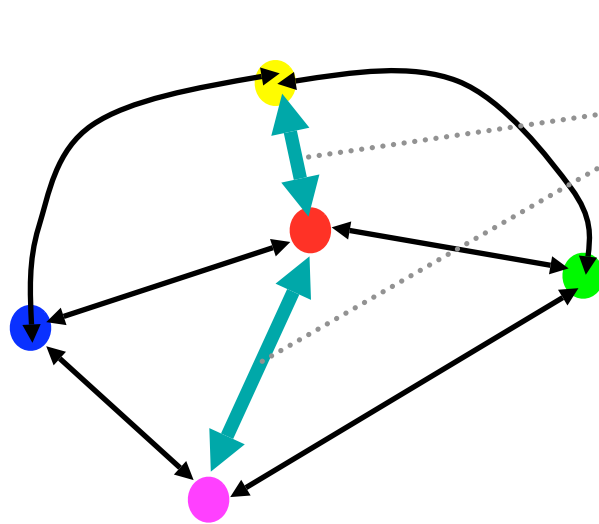
adjacency



adjacency
relations

- At all times the disc (red) is adjacent to the fossa (yellow)
- At all times the disc (red) is adjacent to the condyle (pink)

adjacency



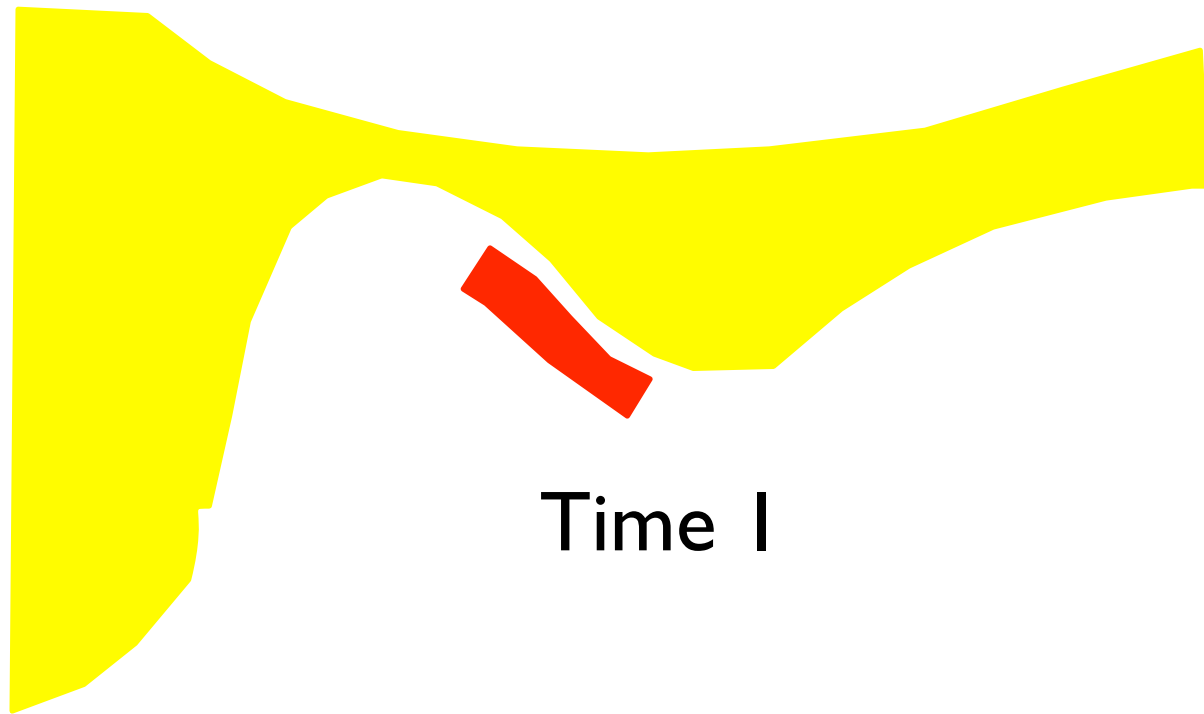
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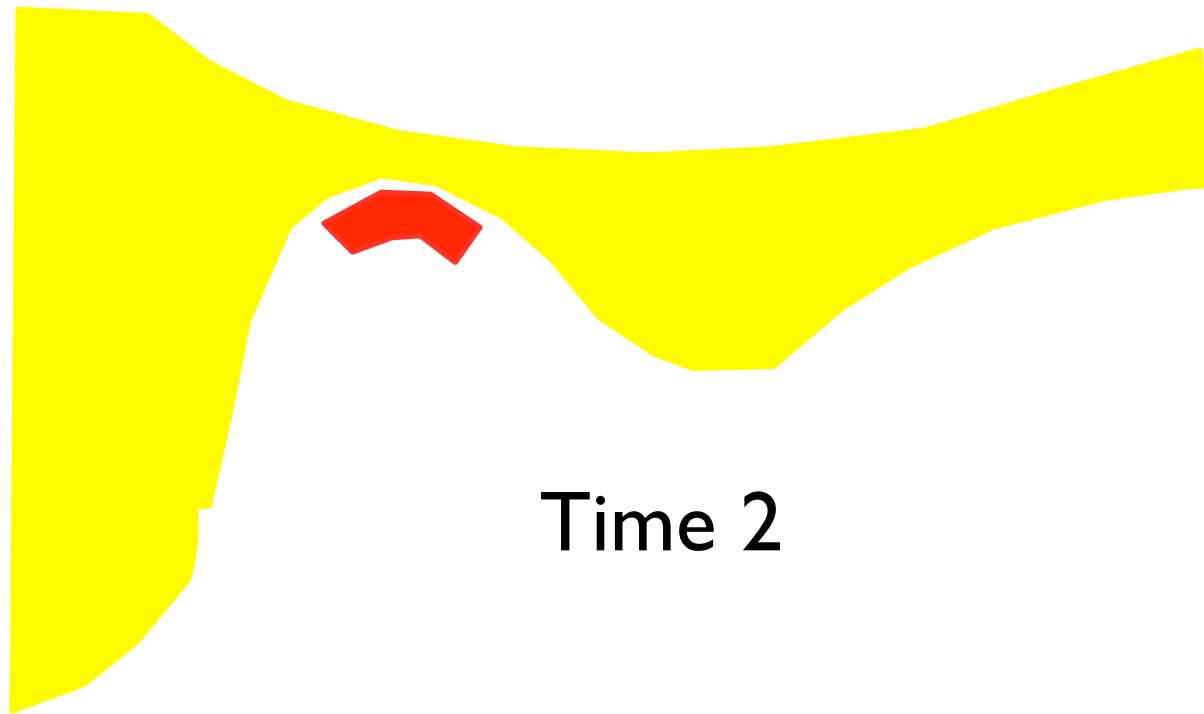
↓

But at **different** times the **disc** may be adjacent to **different** parts of the **fossa** / **condyle**

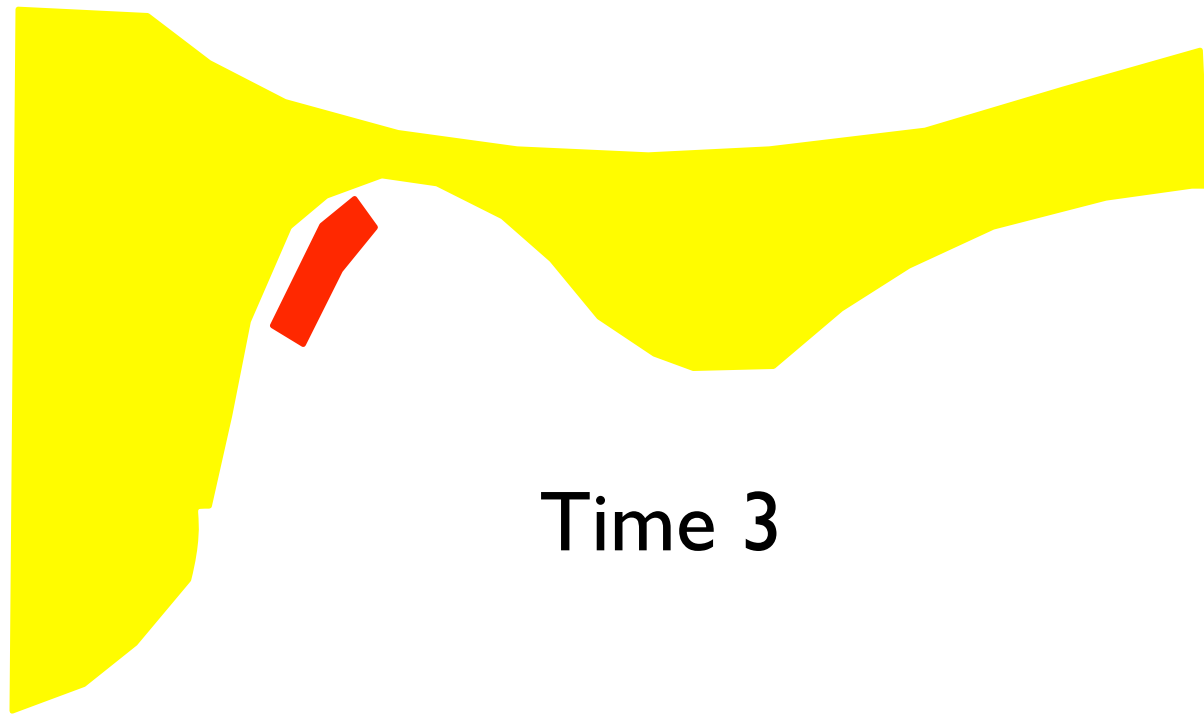
Adjacency **disc-fossa**



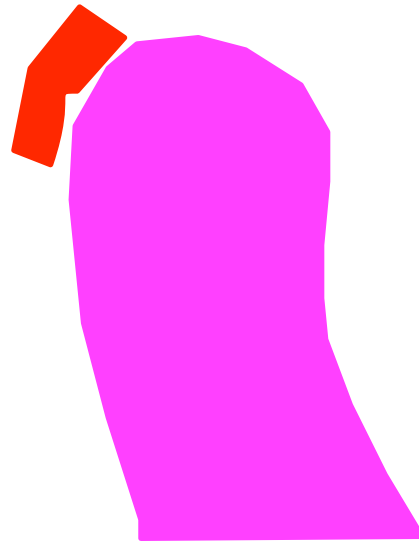
Adjacency **disc**-fossa



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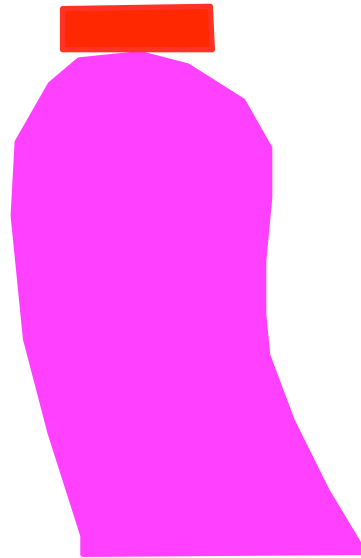


Adjacency disc-condyle



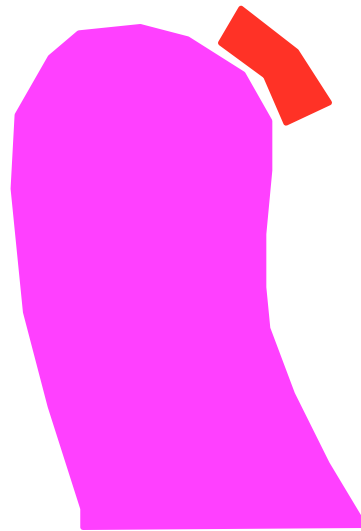
Time I

Adjacency **disc**-condyle



Time 2

Adjacency **disc**-condyle



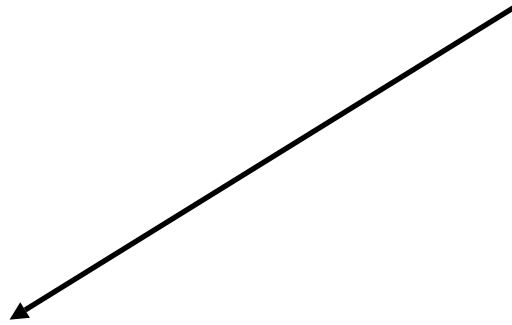
Time 3

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Ordering relations

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Refining adjacency
relation between
disc and **fossa**

Ordering relations

```
graph TD; A[Ordering relations] --> B[Refining adjacency relation between disc and fossa]; A --> C[Refining adjacency relation between disc and condyle];
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Refining adjacency
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Refining adjacency
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Refining adjacency
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Refining adjacency
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disc and **condyle**

Specifying relative
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graph TD; A[Ordering relations] --> B[Refining adjacency relation between disc and fossa]; A --> C[Specifying relative location of condyle and fossa]; A --> D[Refining adjacency relation between disc and condyle];
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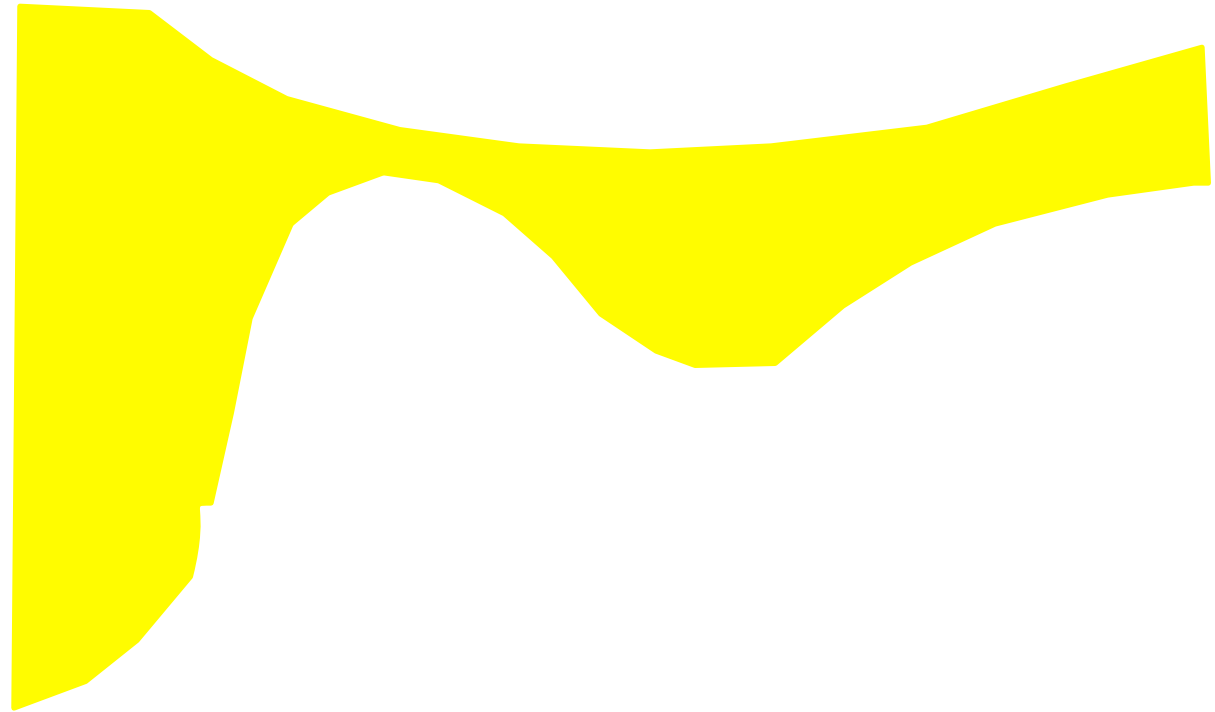
Refining adjacency
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Specifying relative
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Refining adjacency
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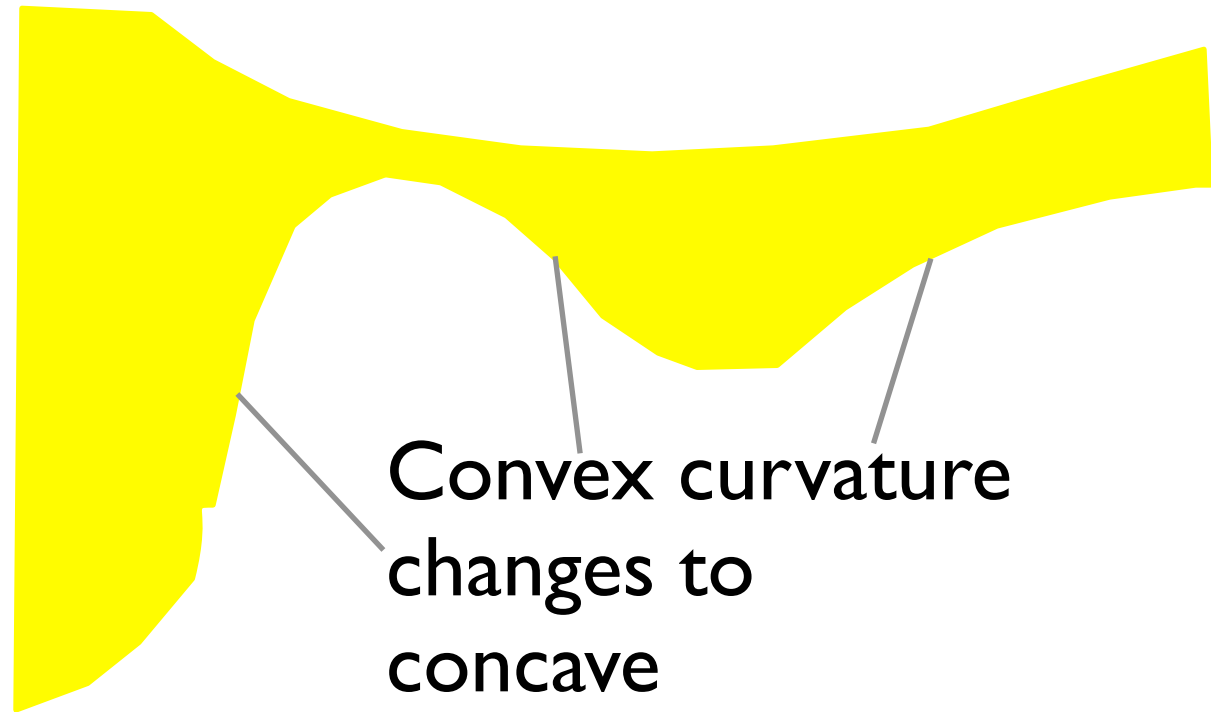
Shape landmarks of the fossa

Rigid does not
Change shape
(bones)



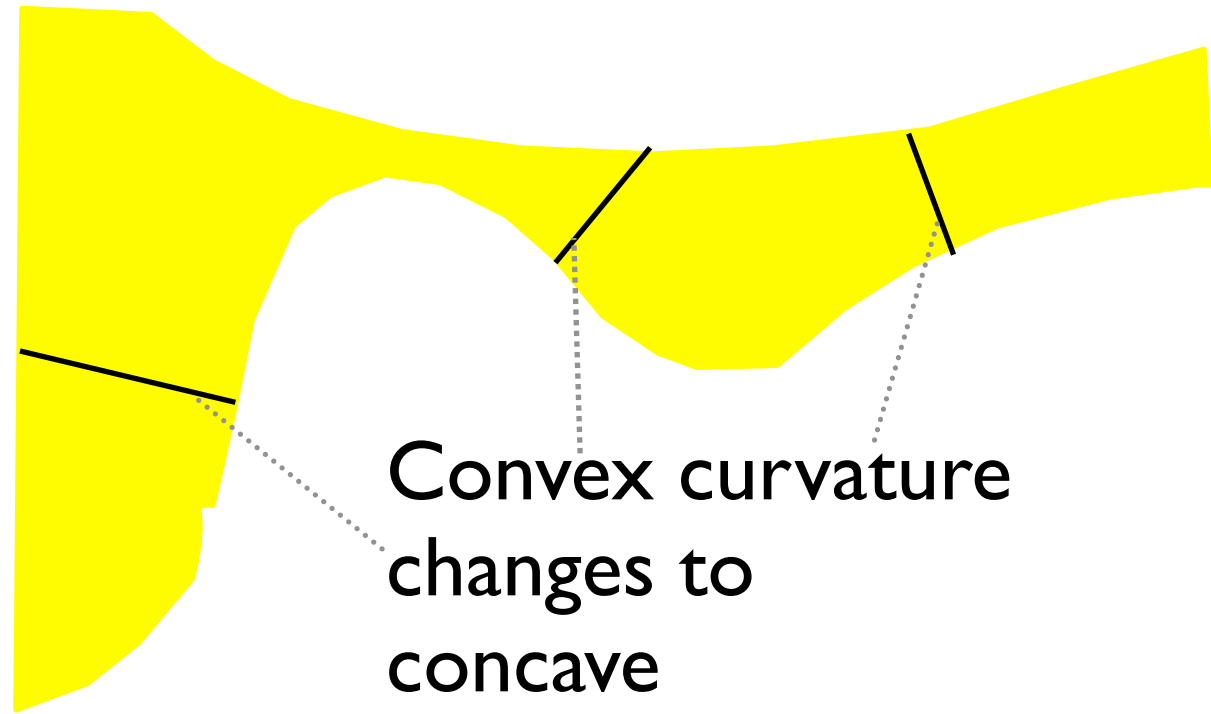
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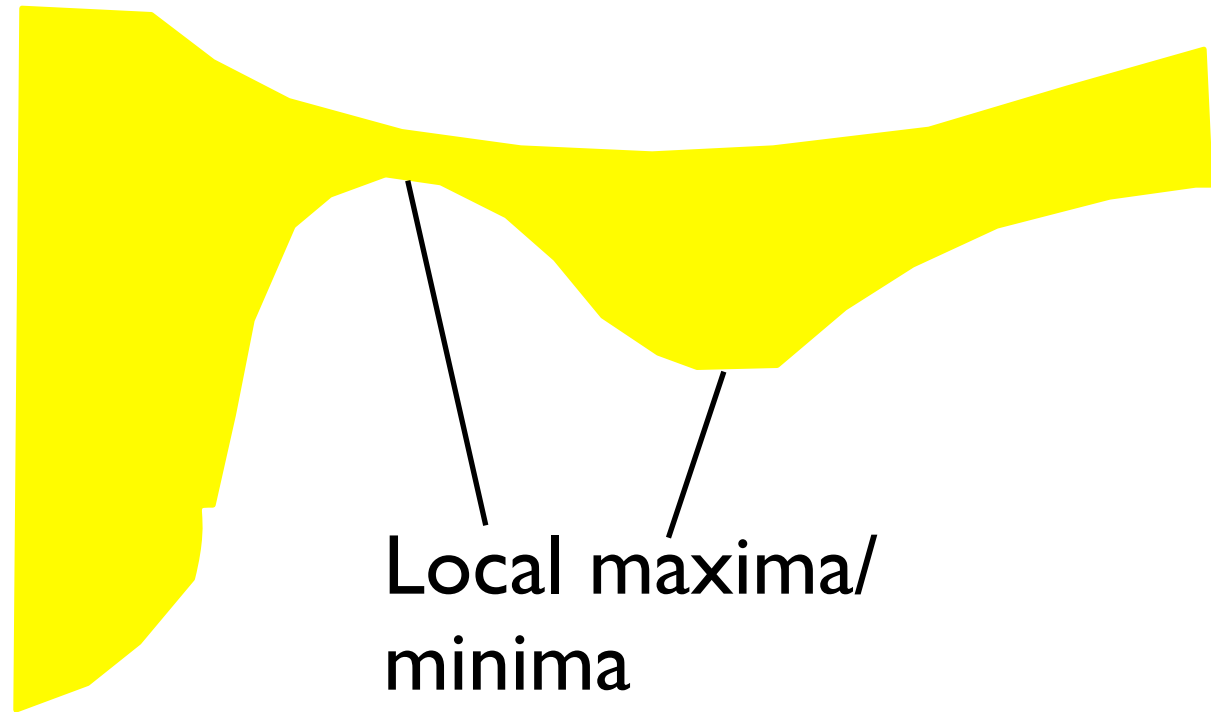
Fiat boundaries

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Shape landmarks of the fossa

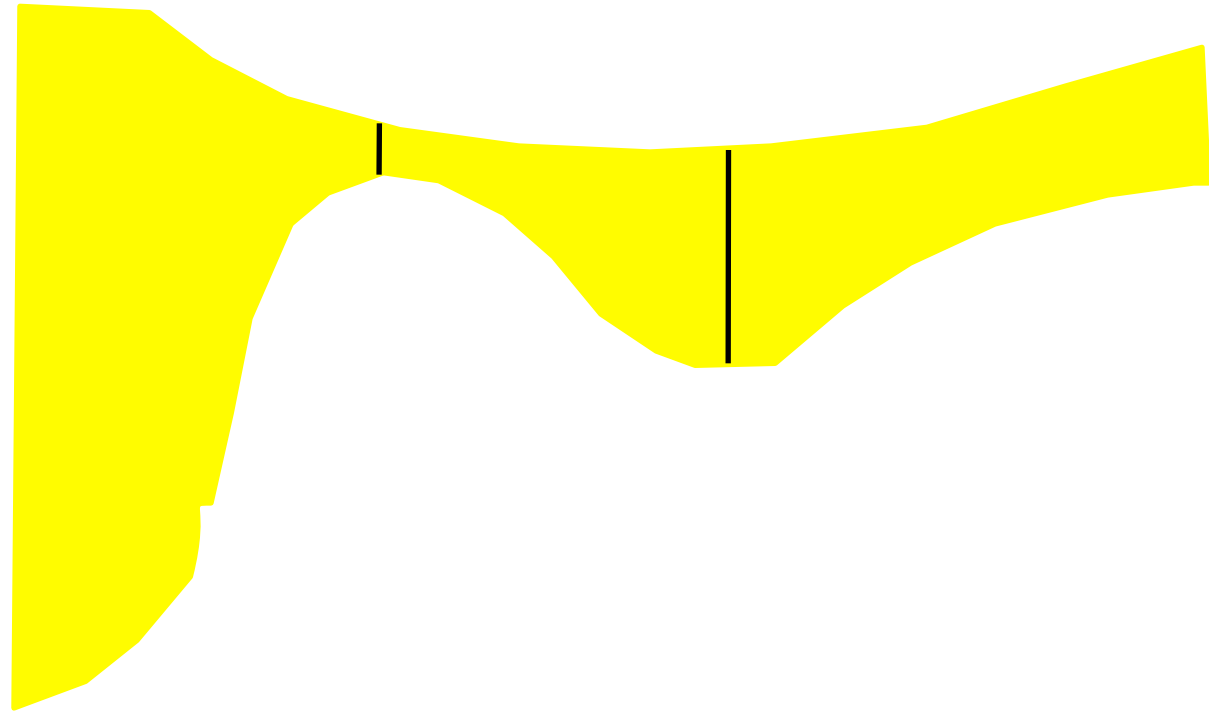
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Local maxima/
minima

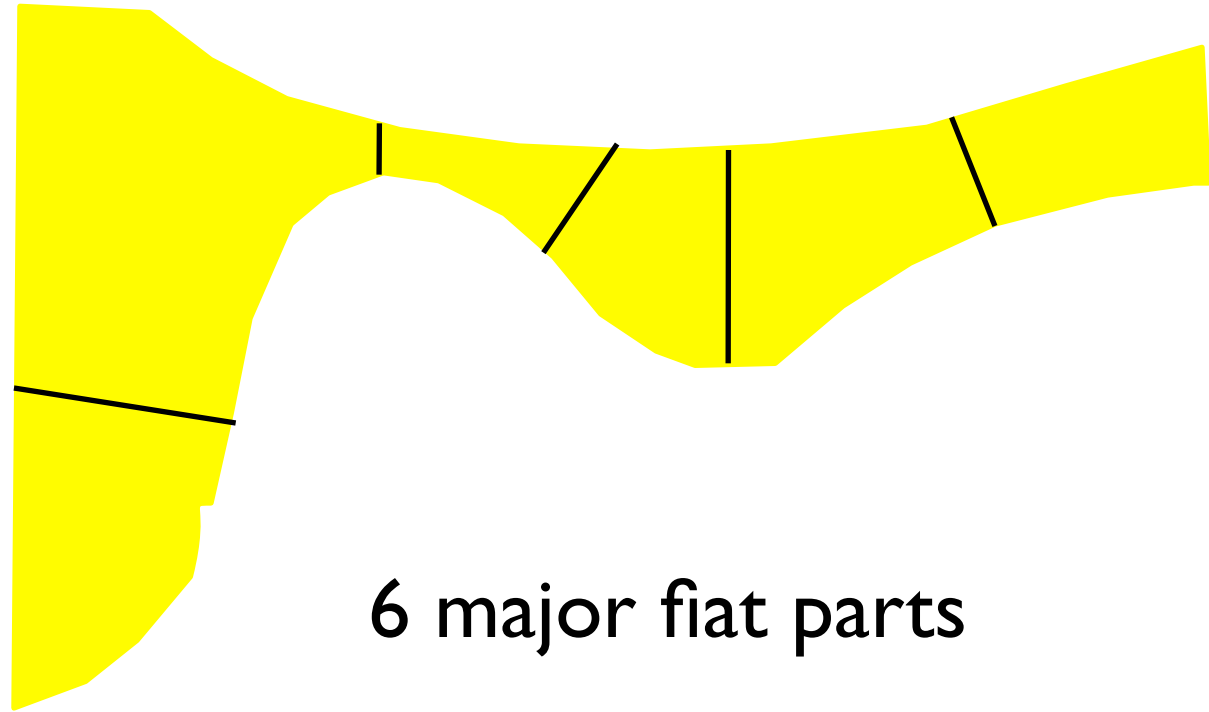
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Fiat boundaries

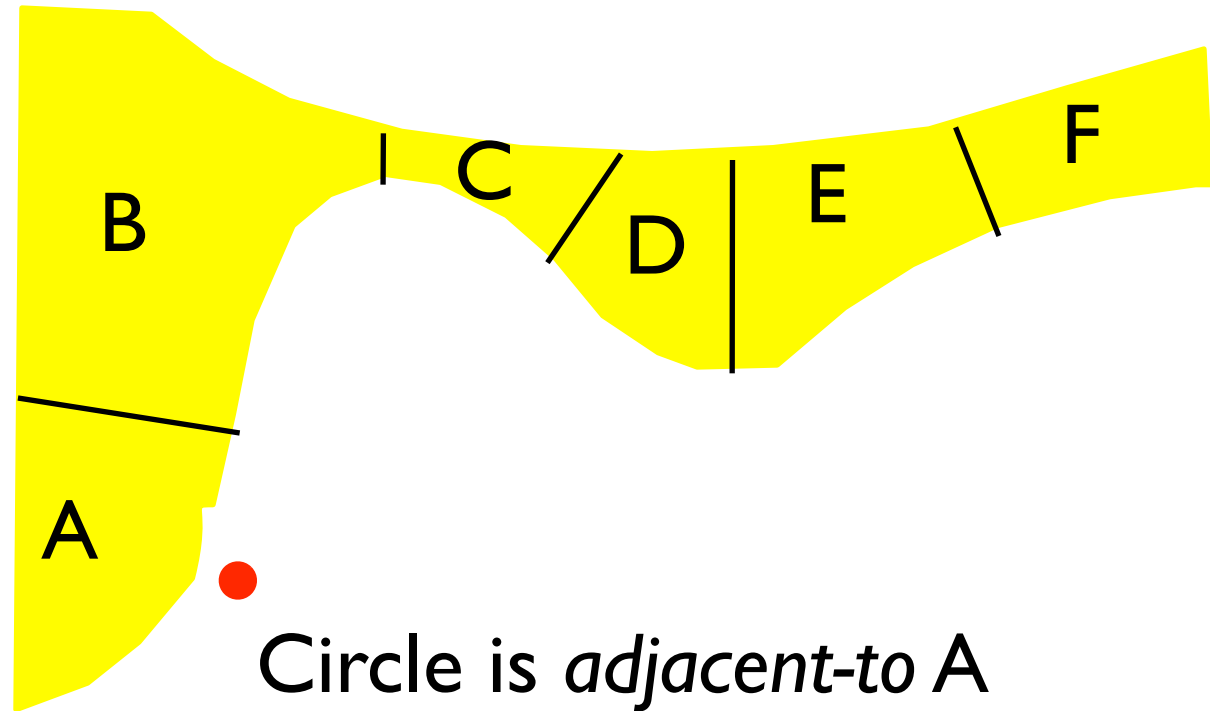
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6 major fiat parts

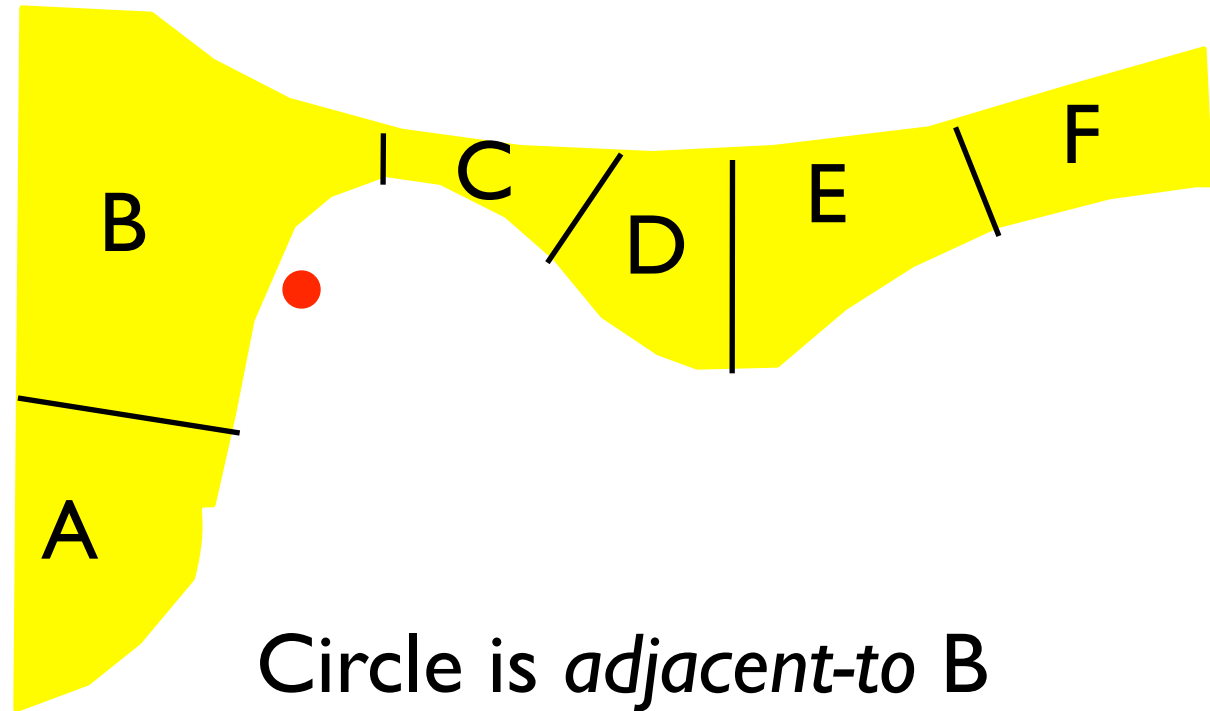
Frames of reference

Rigid does not
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(bones)



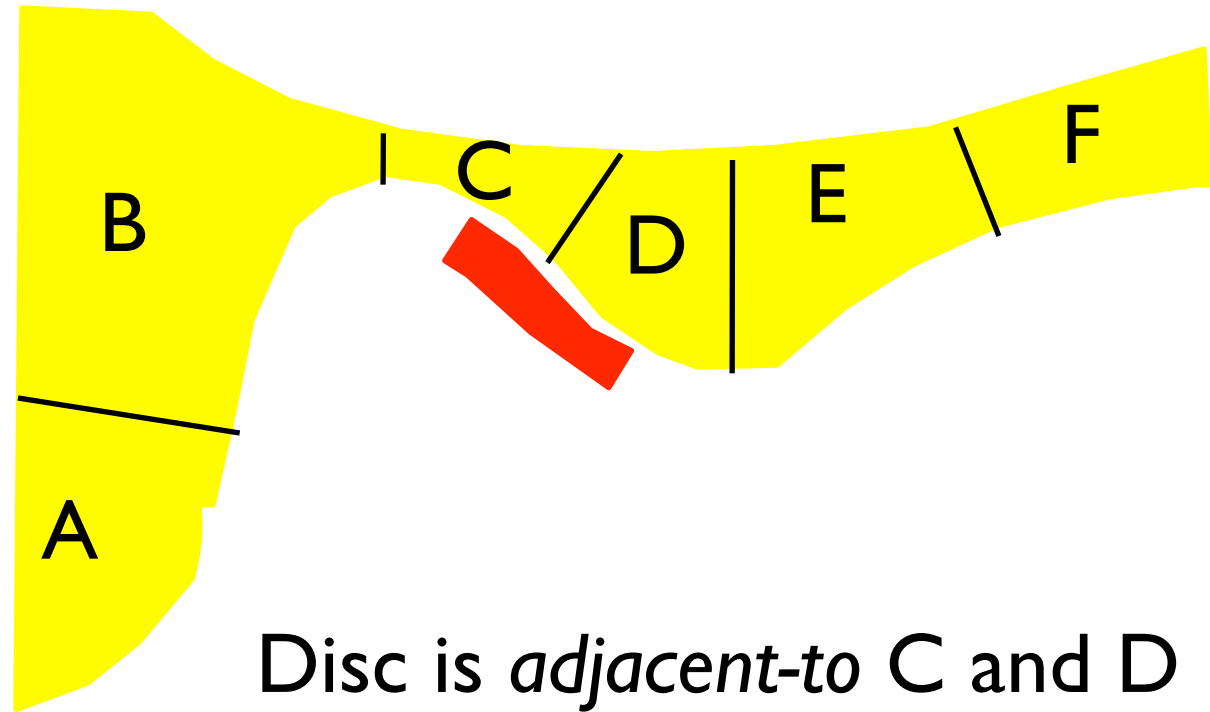
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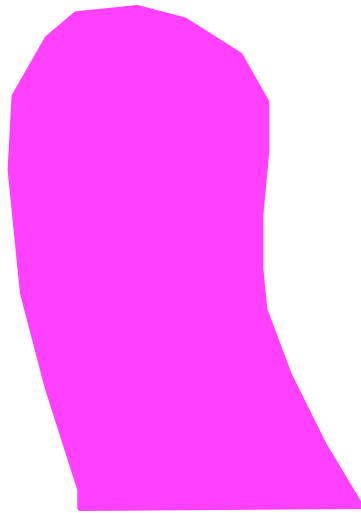
Ordering relations

Refining adjacency
relation between
disc and **fossa**

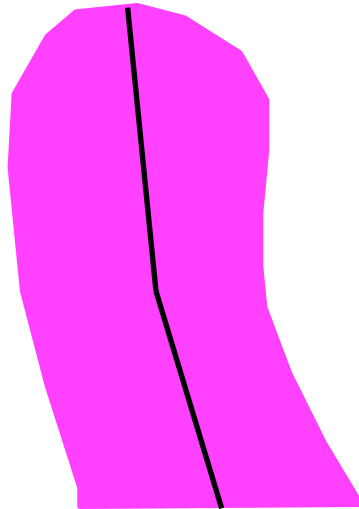
Refining adjacency
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Specifying relative
location of **condyle** and
fossa

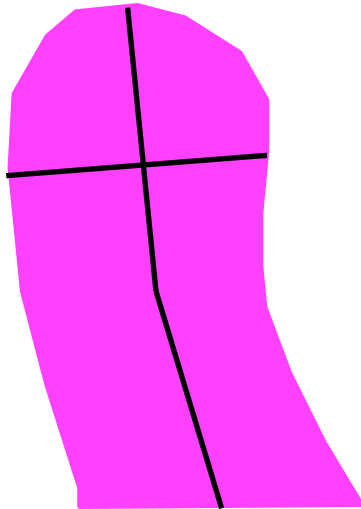
Shape landmarks of the condyle as frame of reference



Shape landmarks of the condyle as frame of reference

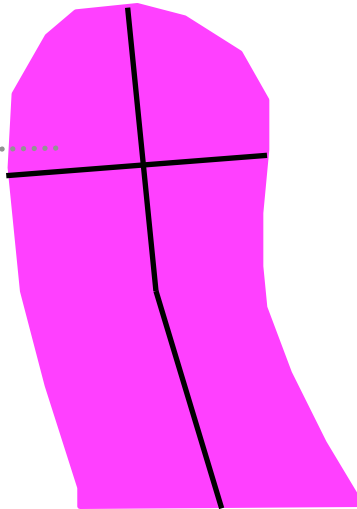


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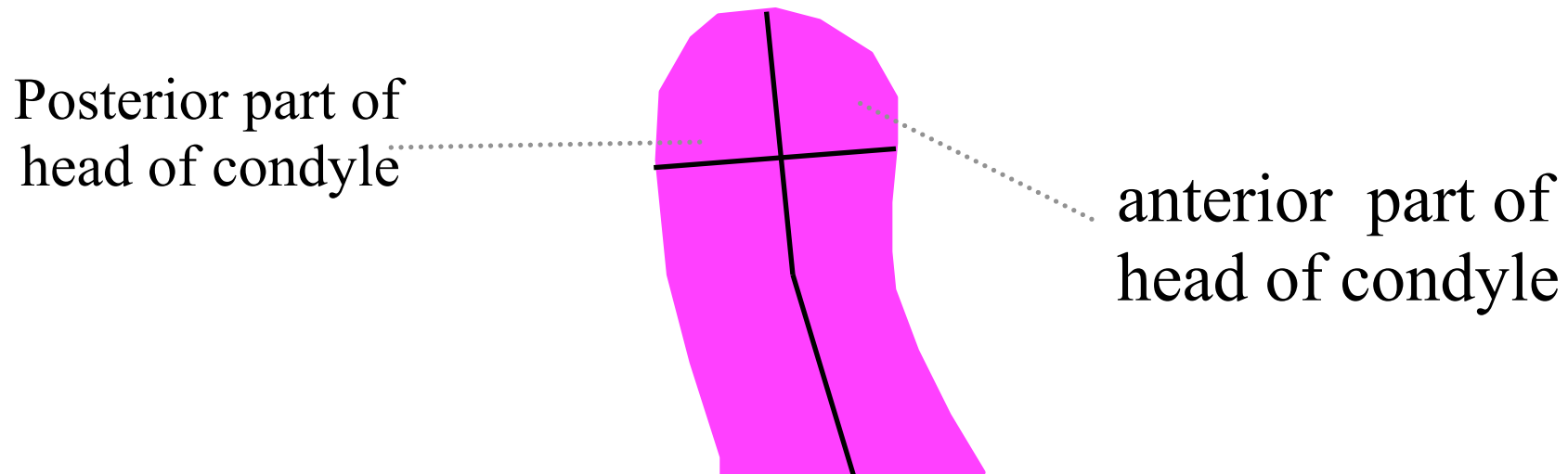


Shape landmarks of the condyle as frame of reference

Posterior part of
head of condyle

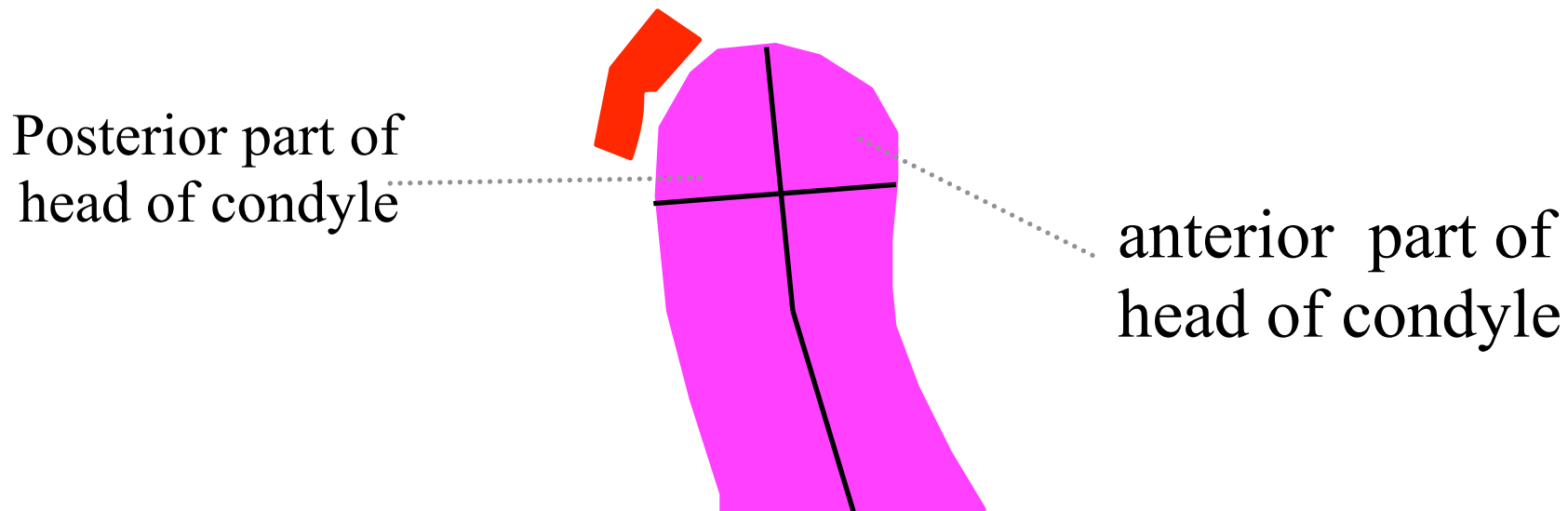


Shape landmarks of the condyle as frame of reference



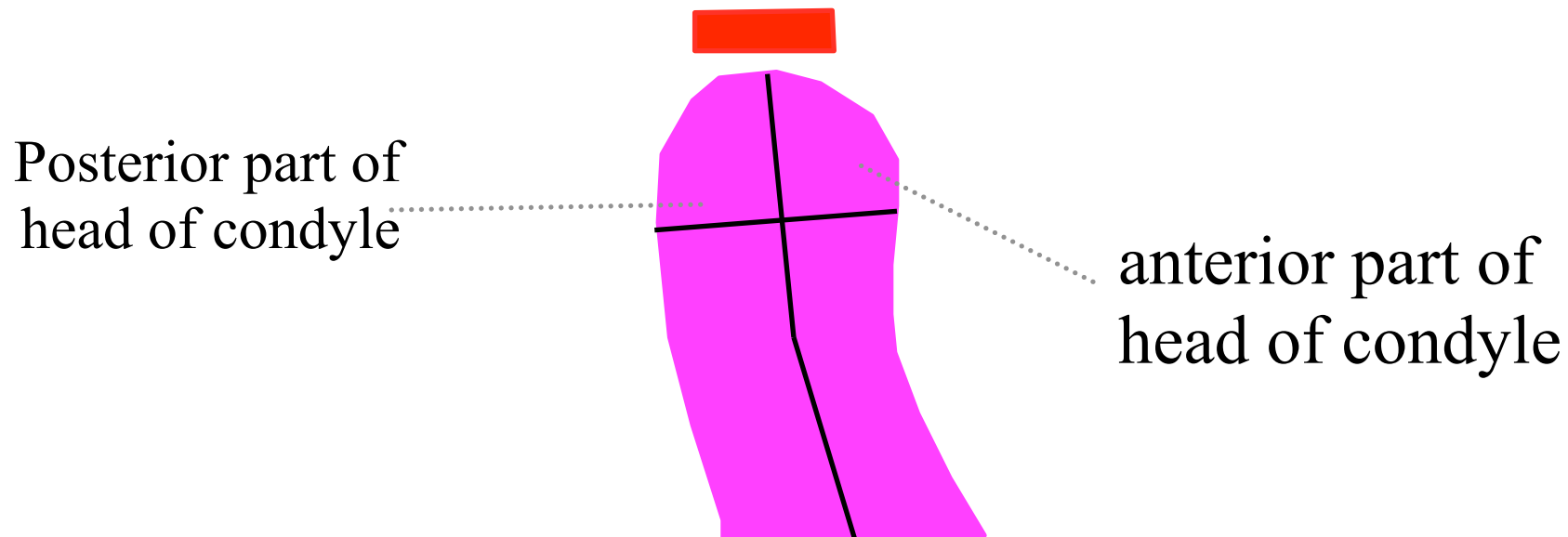
Shape landmarks of the condyle as frame of reference

Disc is adjacent to the posterior part of the head of the condyle



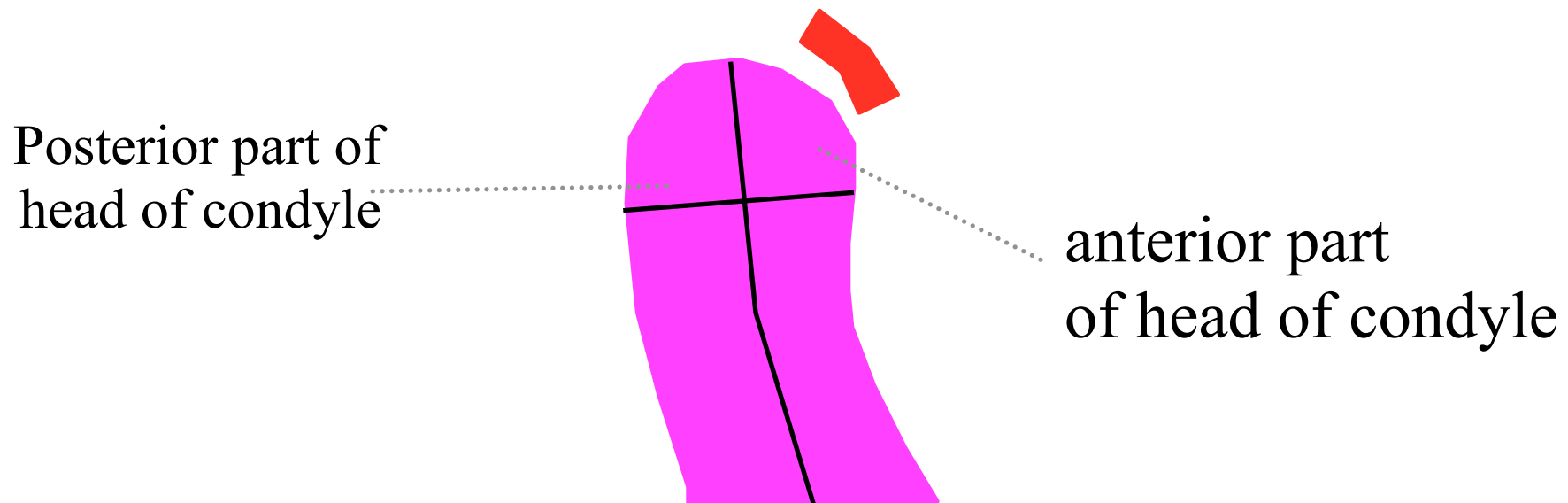
Shape landmarks of the condyle as frame of reference

Disc is adjacent to posterior and anterior parts of
the head of the condyle



Shape landmarks of the condyle as frame of reference

Disc is adjacent to the
anterior head of the condyle



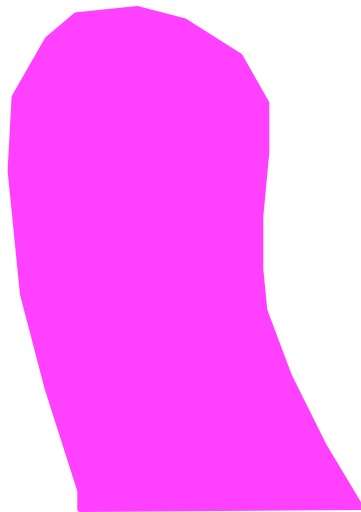
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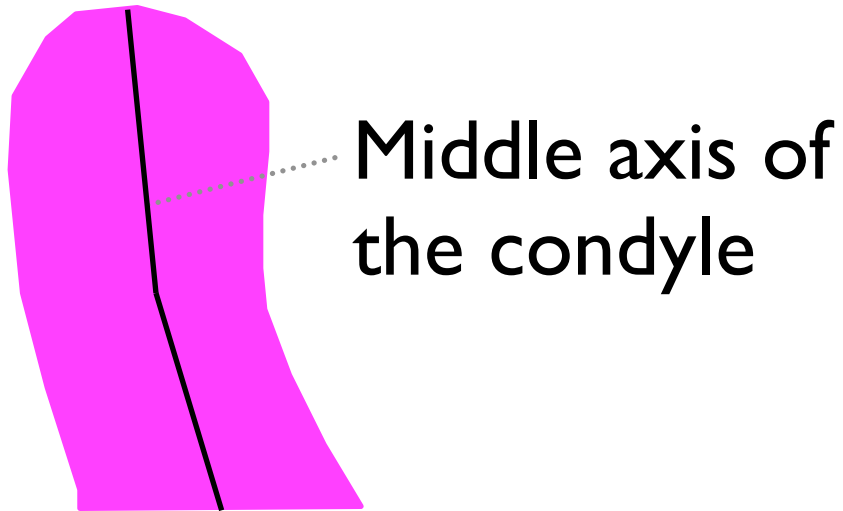
Refining adjacency
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Specifying relative
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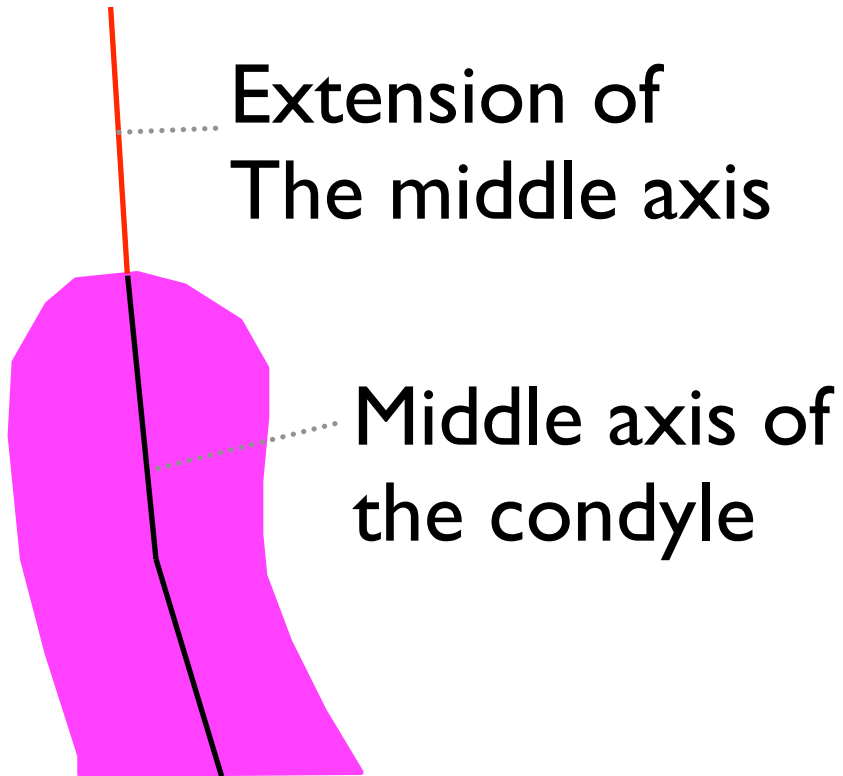
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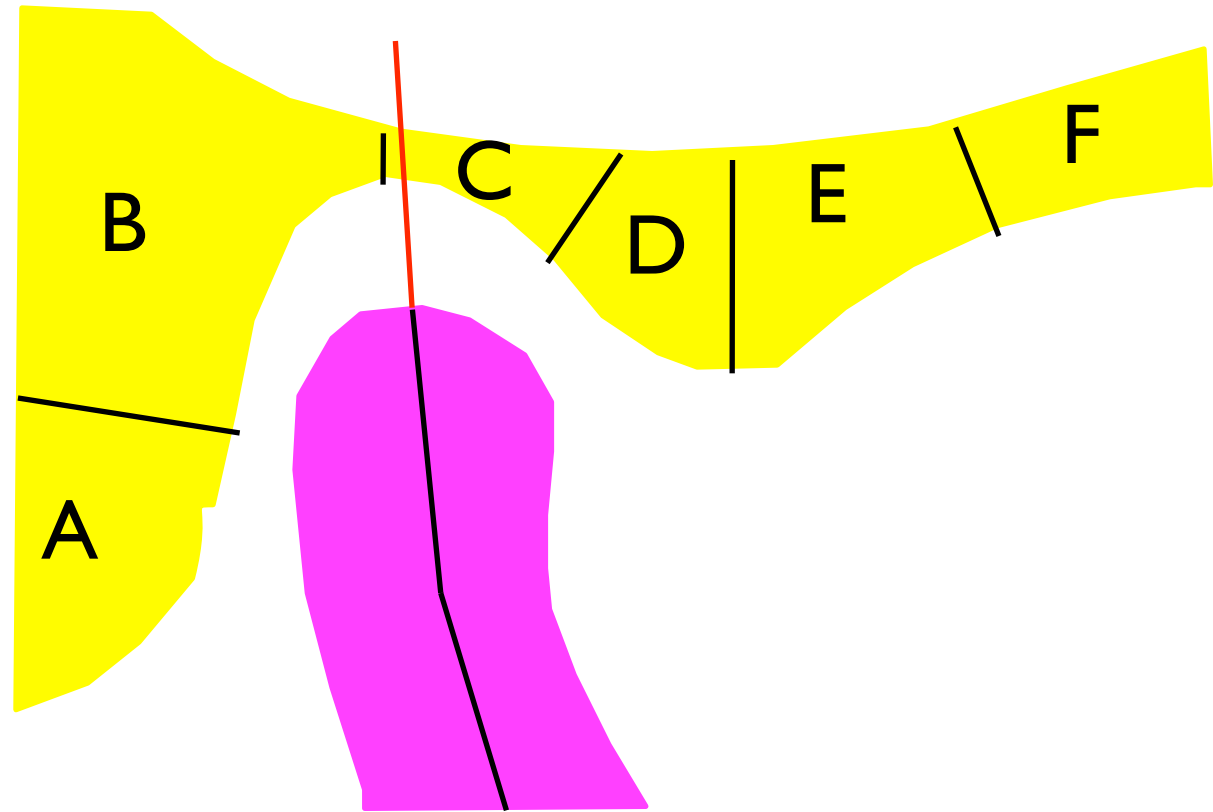


Shape landmarks of the condyle



Frames of reference

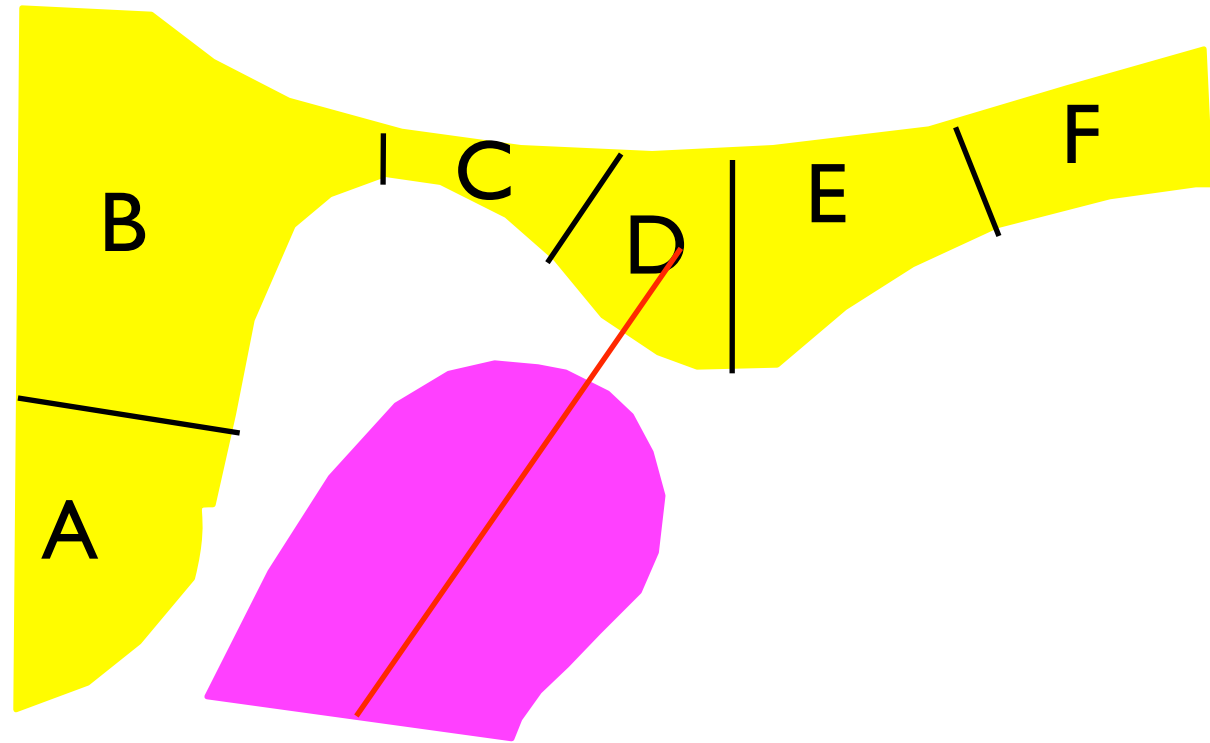
Rigid does not
change shape
(bones)



The extension of the axis of the condyle
intersects the fossa in region C

Frames of reference

Rigid does not
change shape
(bones)



The extension of the axis of the condyle
intersects the fossa in region D

Bringing the various ordering
relations together

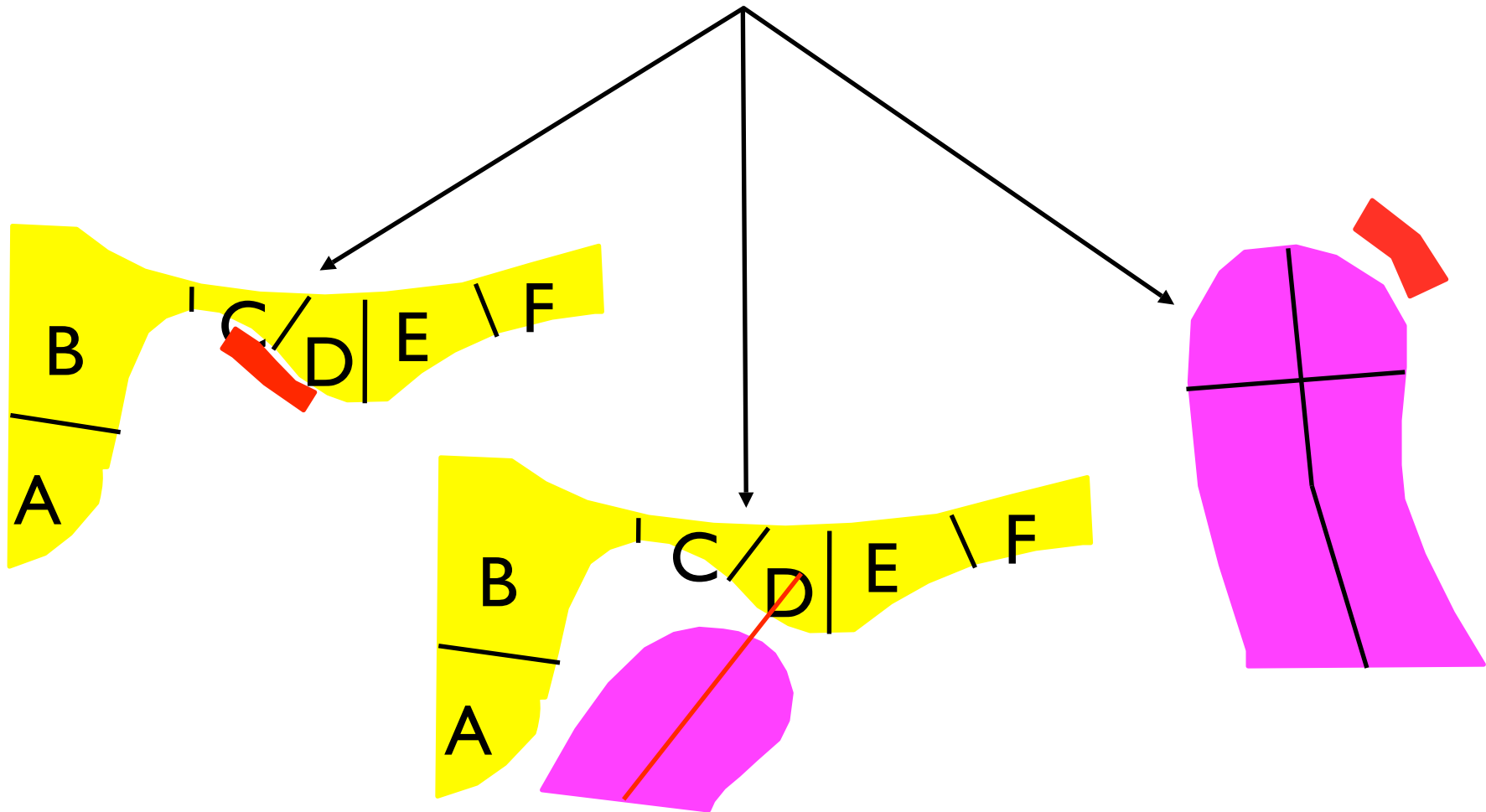
Ordering relations

Refining adjacency
relation between
disc and **fossa**

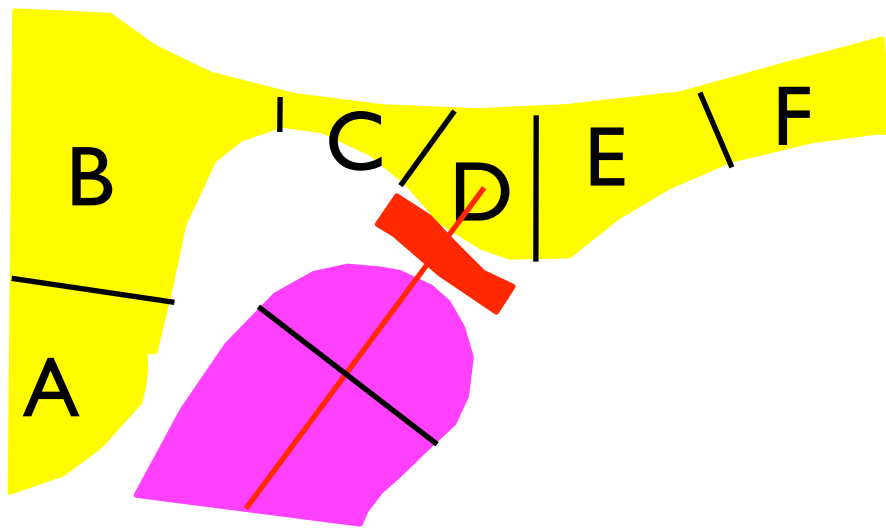
Refining adjacency
relation between
disc and **condyle**

Specifying relative
location of **condyle** and
fossa

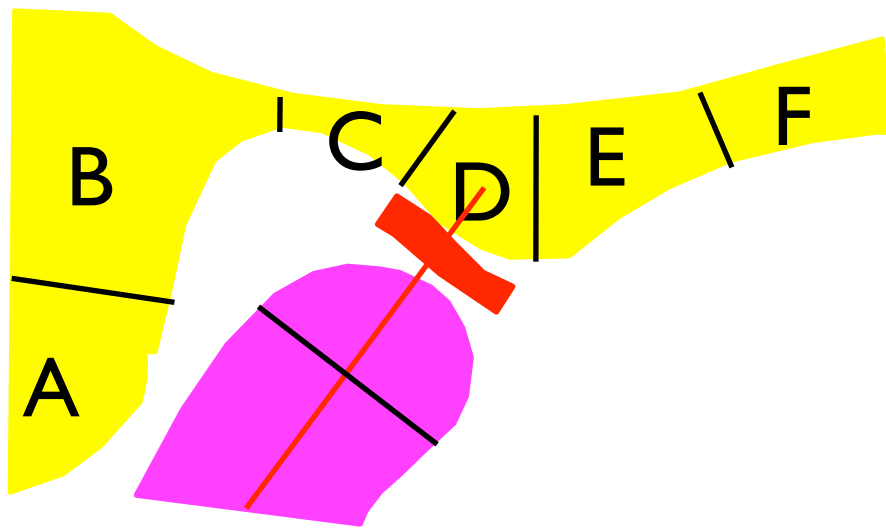
Ordering relations



bringing together multiple ordering structures:
two frames of reference locate the position of the disc
and condyle with respect to each other and to the fossa

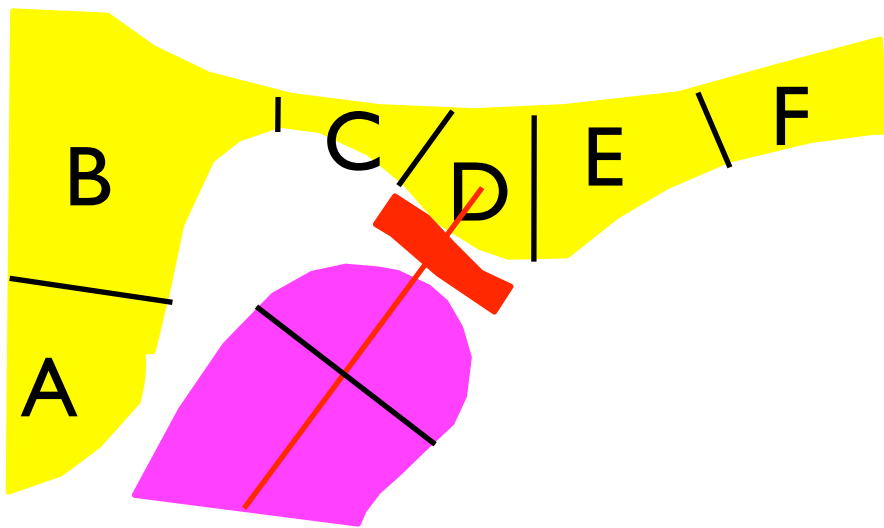


bringing together multiple ordering structures:
two frames of reference locate the position of the disc
and condyle with respect to each other and to the fossa



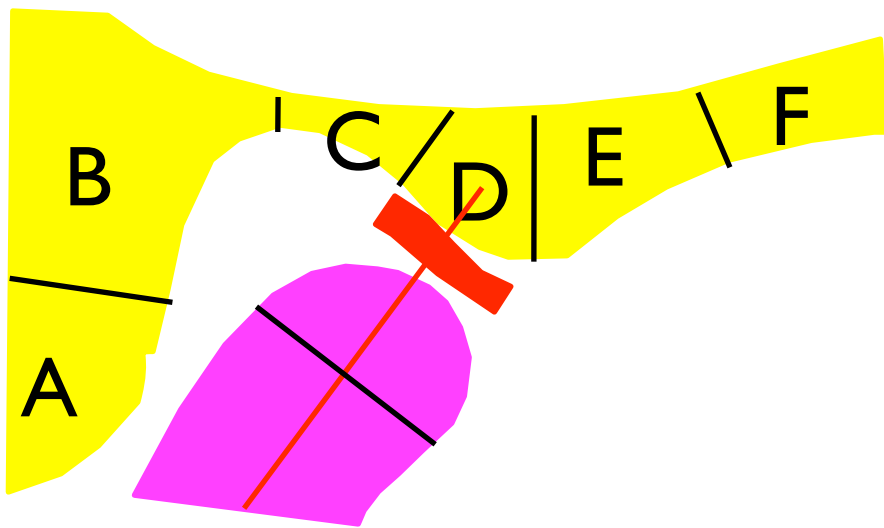
- The extension of the axis of the condyle *intersects* the fossa in region D

bringing together multiple ordering structures:
two frames of reference locate the position of the disc
and condyle with respect to each other and to the fossa



- The extension of the axis of the condyle *intersects* the fossa in region D
- The disc is *adjacent-to* fossa regions C and D

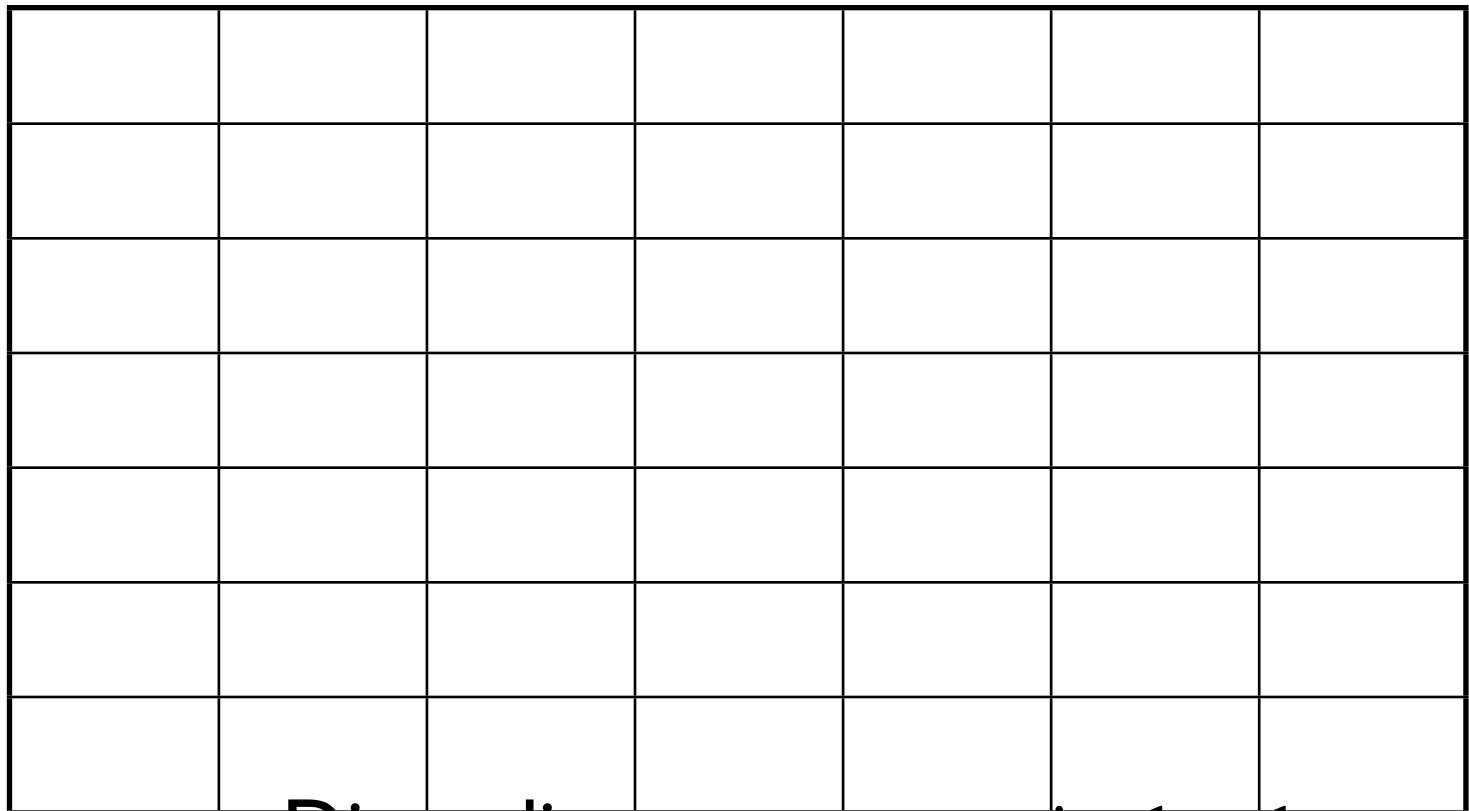
bringing together multiple ordering structures:
two frames of reference locate the position of the disc
and condyle with respect to each other and to the fossa



- The extension of the axis of the condyle *intersects* the fossa in region D
- The disc is *adjacent-to* fossa regions C and D
- The disc is adjacent to the posterior and anterior head of the condyle

we now have a three dimensional combinatorial
space of possible ordering relations
between fossa, condyle, and disc

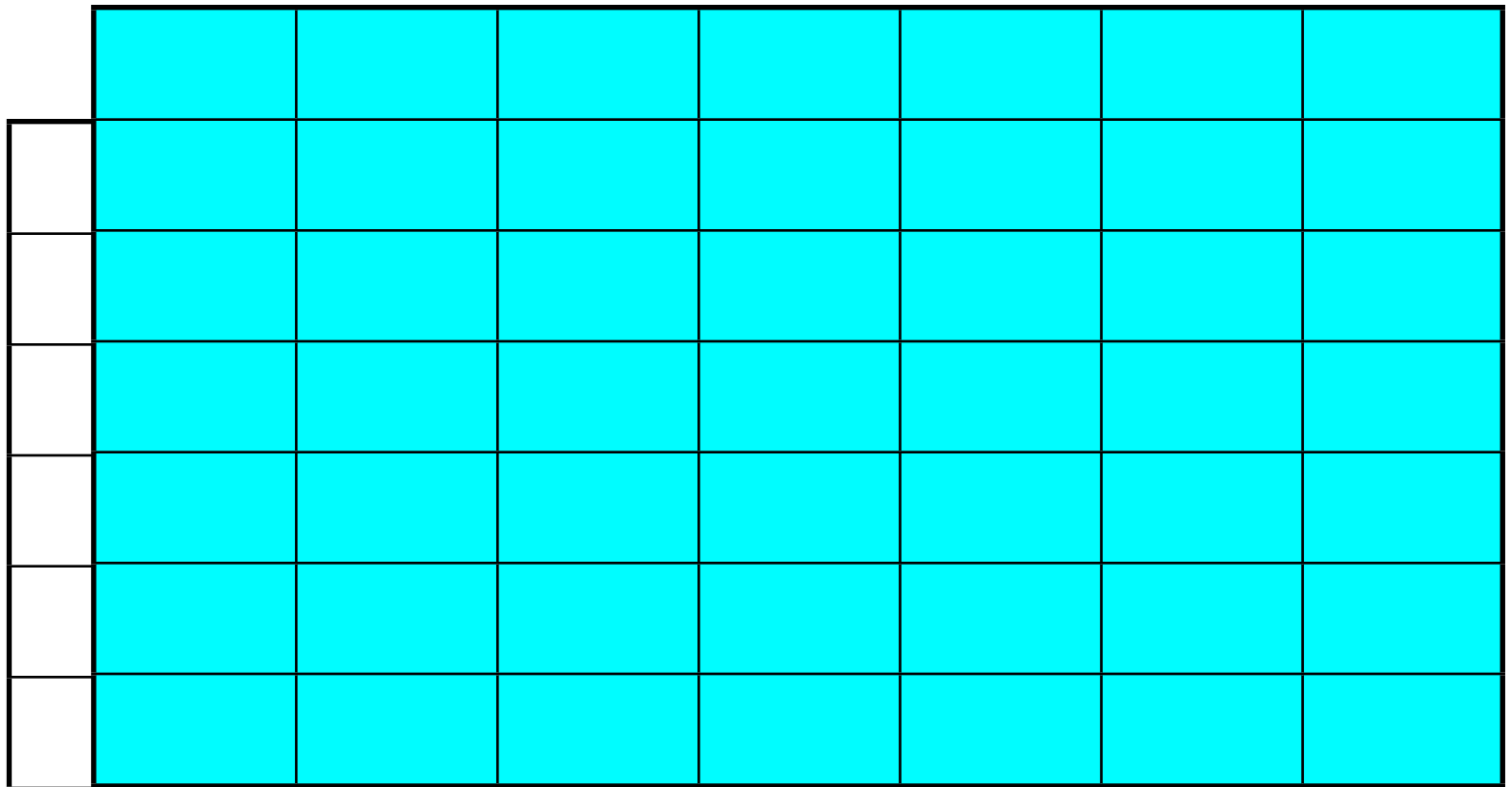
All combinatorial possible constellations



Disc adjacent to posterior head

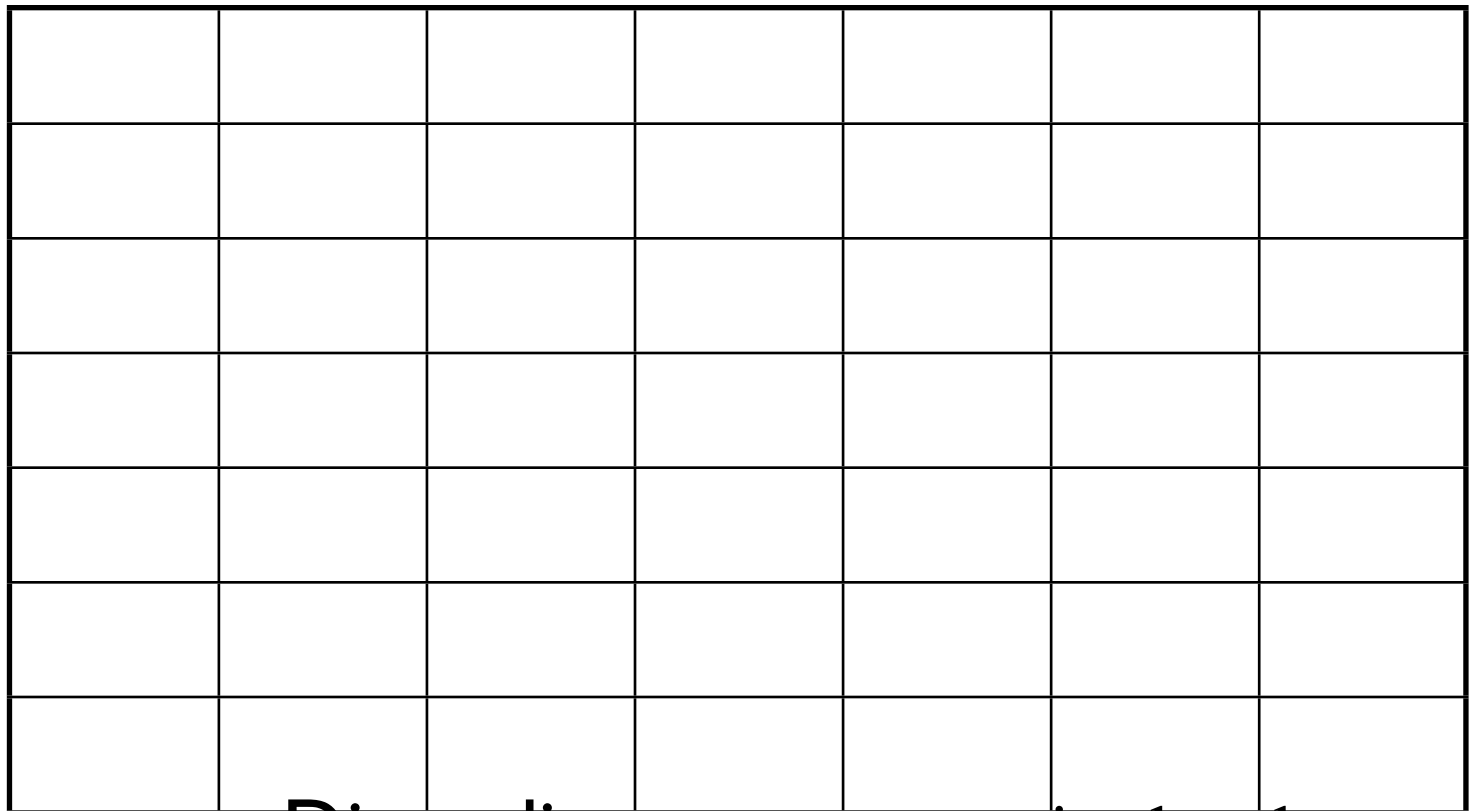
All combinatorial possible constellations

Disc adjacent to anterior head



Disc adjacent to posterior head

All combinatorial possible constellations



Disc adjacent to posterior head

All combinatorial possible constellations

Disc is adjacent to fossa region

	A	B	C	D	E	F

Disc adjacent to posterior head

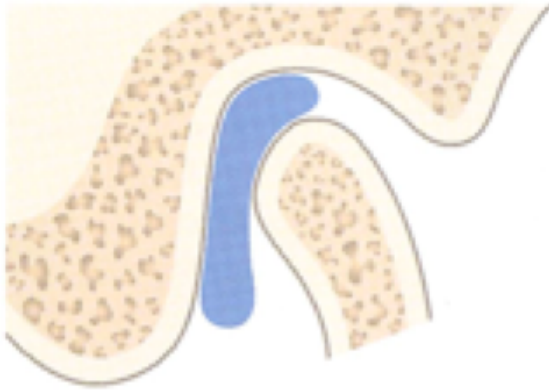
All combinatorial possible constellations

Disc is adjacent to fossa region

Axis
Of
Condyle
intersects

	A	B	C	D	E	F
A						
B						
C						
D						
E						
F						

Disc adjacent to posterior head



a

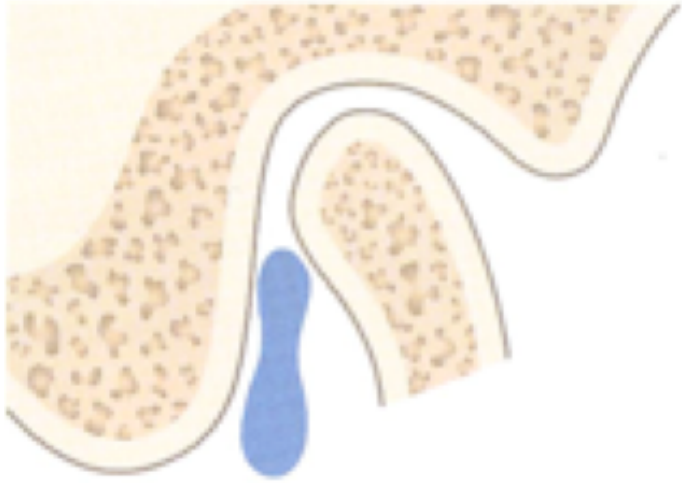
Central 41%

Disc is adjacent to fossa region

Axis
Of
Condyle
intersects

	A	B	C	D	E	F
A						
B	X	X	X			
C						
D						
E						
F						

Disc adjacent to posterior & anterior head

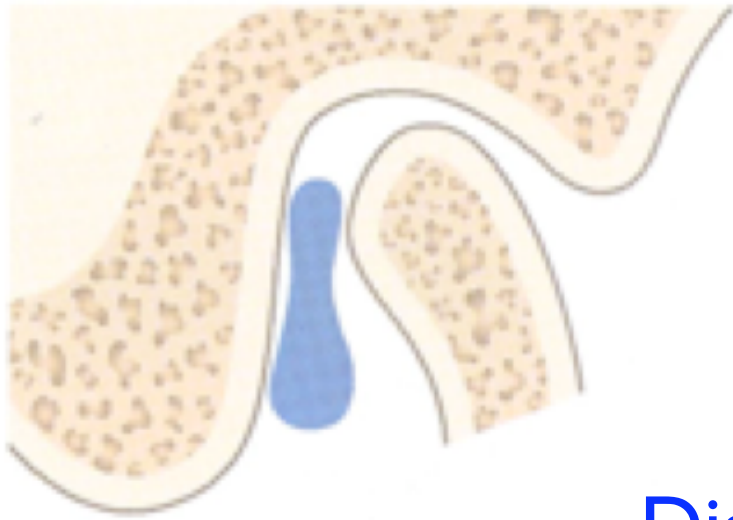


Disc is adjacent to fossa region

Axis
Of
Condyle
intersects

	A	B	C	D	E	F
A						
B	X					
C						
D						
E						
F						

Disc adjacent to anterior neck

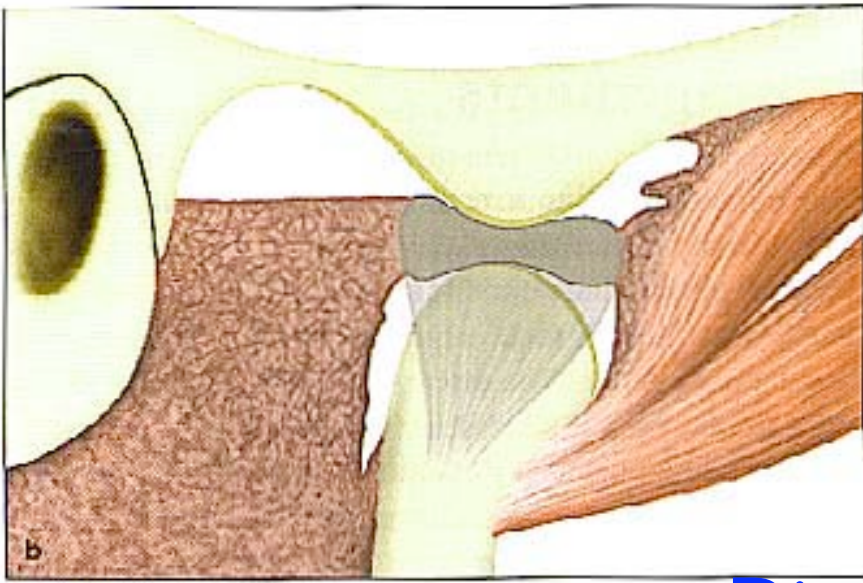


Disc is adjacent to fossa region

Axis
Of
Condyle
intersects

	A	B	C	D	E	F
A						
B	X	X				
C						
D						
E						
F						

Disc adjacent to anterior head & neck



Disc is adjacent to fossa region

Axis
Of
Condyle
intersects

	A	B	C	D	E	F
A						
B						
C						
D						
E				X	X	
F						

Disc adjacent to posterior & anterior head

TMJ DYNAMICS: NORMAL & ABNORMAL

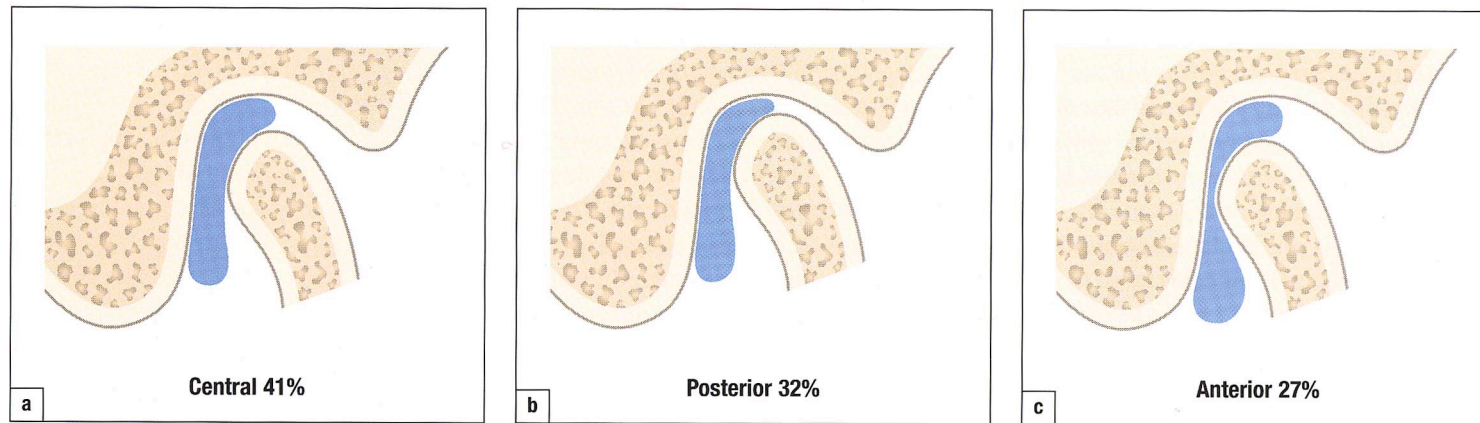
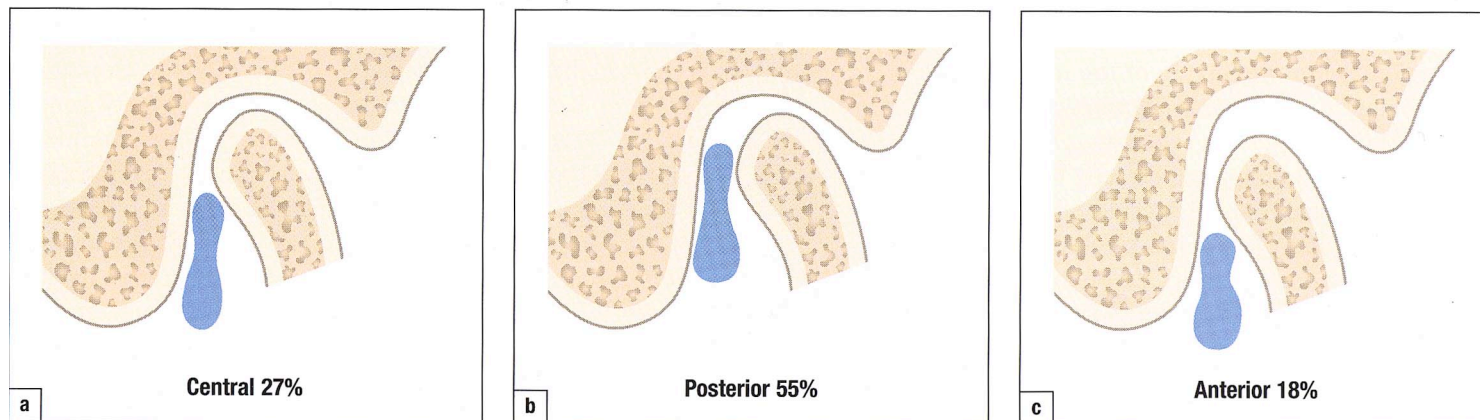


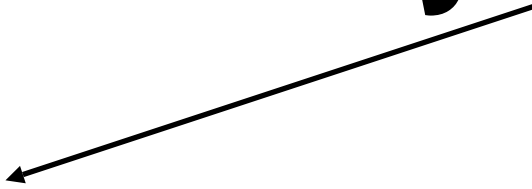
Figure 5.6. Condyle position in joints with normal disc position.



Conclusions/ Methodology

TMJ ontology

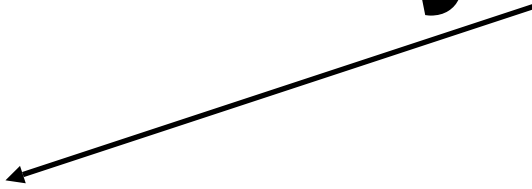
TMJ ontology



Mereology

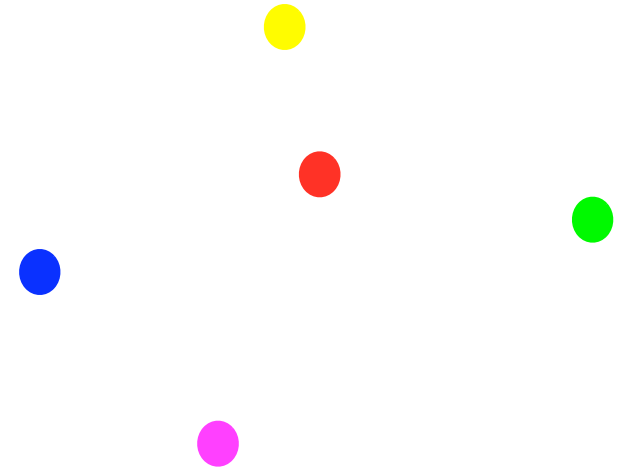
- How many parts
- What kind of parts

TMJ ontology

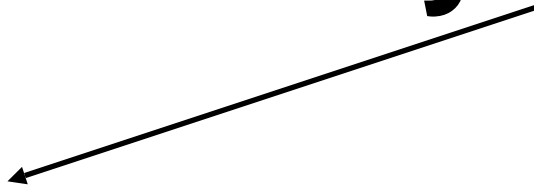


Mereology

- How many parts
- What kind of parts



TMJ ontology



Mereology

- How many parts
- What kind of parts

Topology

- Which parts are attached
- Which parts are adjacent



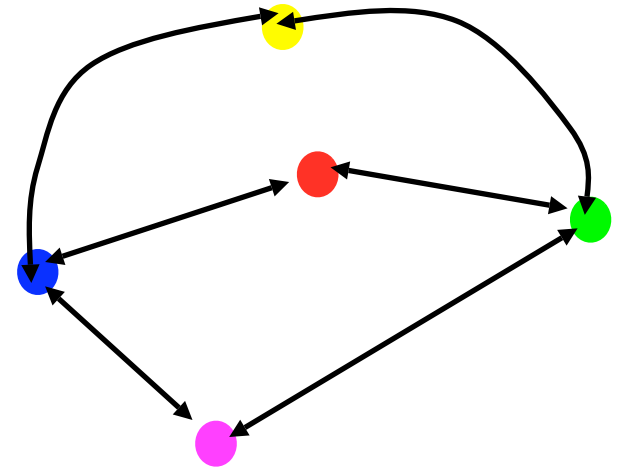
TMJ ontology

Mereology

- How many parts
- What kind of parts

Topology

- Which parts are attached
- Which parts are adjacent



TMJ ontology

```
graph TD; TMJ[TMJ ontology] --> Mereology[Mereology]; TMJ --> Topology[Topology];
```

Mereology

- How many parts
- What kind of parts

Topology

- Which parts are attached
- Which parts are adjacent

TMJ ontology

```
graph TD; TMJ[TMJ ontology] --> Mereology[Mereology]; TMJ --> Topology[Topology]; TMJ --> Qualitative[Qualitative order];
```

Mereology

- How many parts
- What kind of parts

Topology

- Which parts are attached
- Which parts are adjacent

Qualitative order

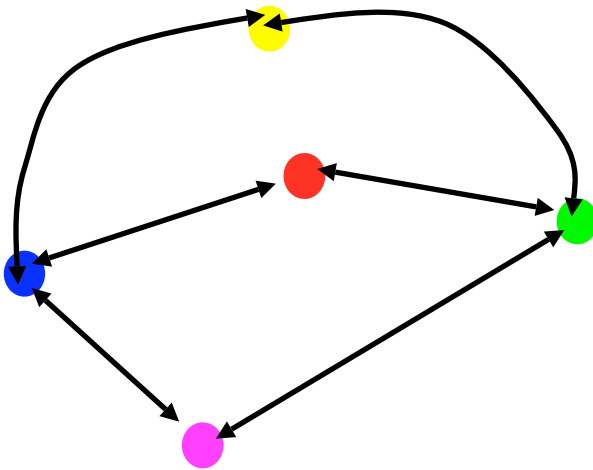
- How are things arranged with respect to each other
- How does relative location change during movement

TMJ ontology

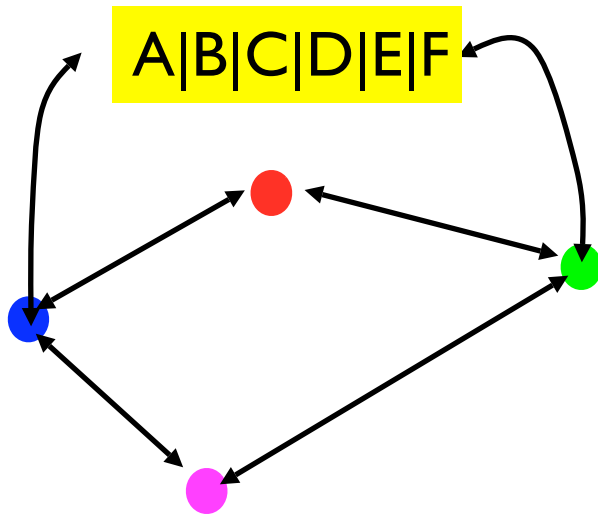


Qualitative order

- How are things arranged with respect to each other
- How does relative location change during movement



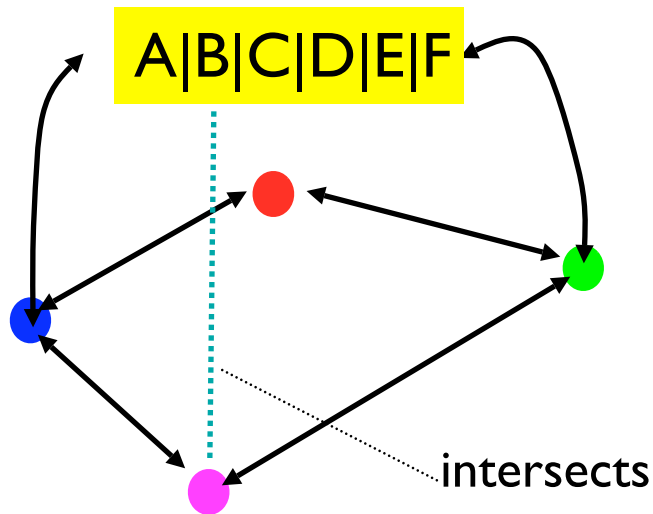
TMJ ontology



Qualitative order

- How are things arranged with respect to each other
- How does relative location change during movement

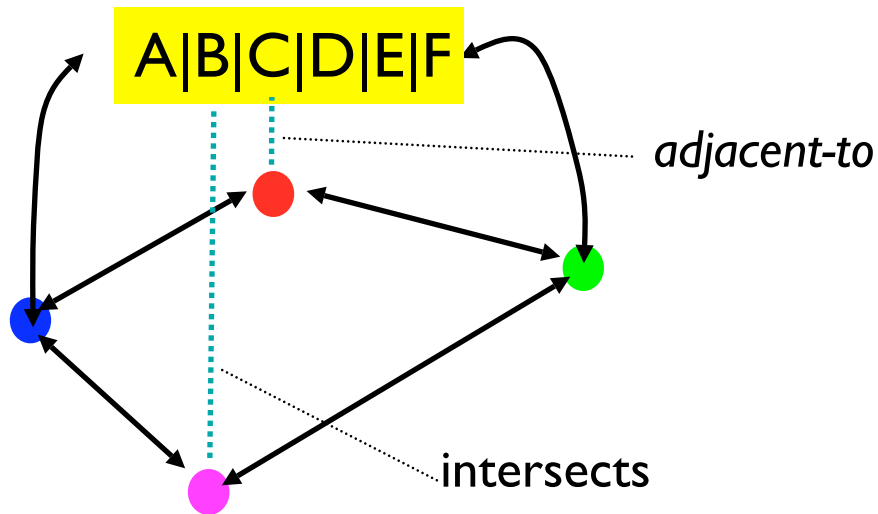
TMJ ontology



Qualitative order

- How are things arranged with respect to each other
- How does relative location change during movement

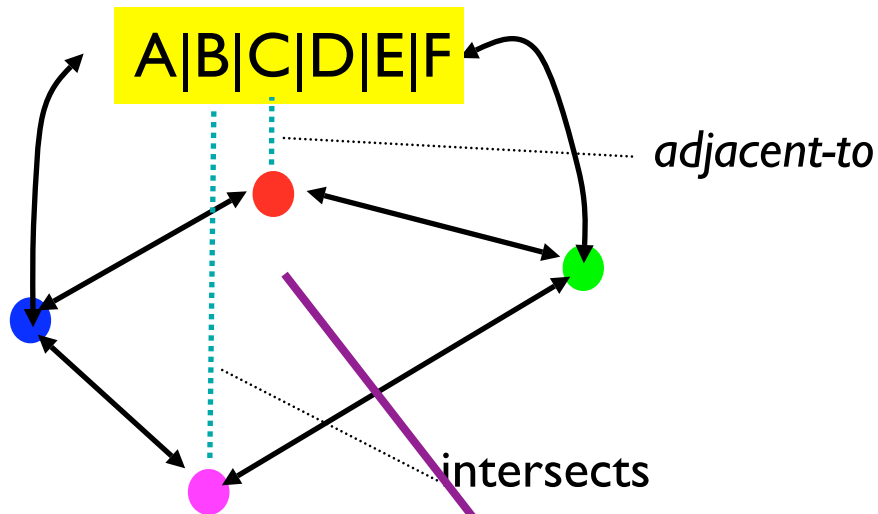
TMJ ontology



Qualitative order

- How are things arranged with respect to each other
- How does relative location change during movement

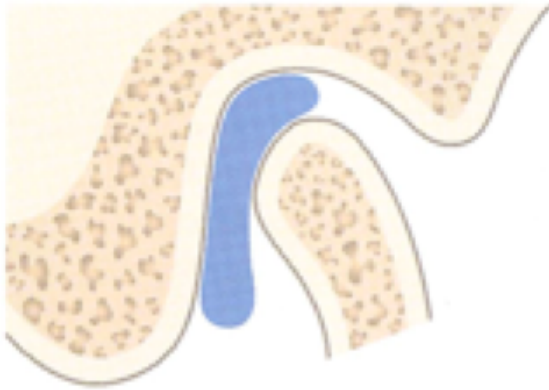
TMJ ontology



Qualitative order

- How are things arranged with respect to each other
- How does relative location change during movement

combinatorial 'space' of possible ordering relations between fossa, condyle, and disc



a

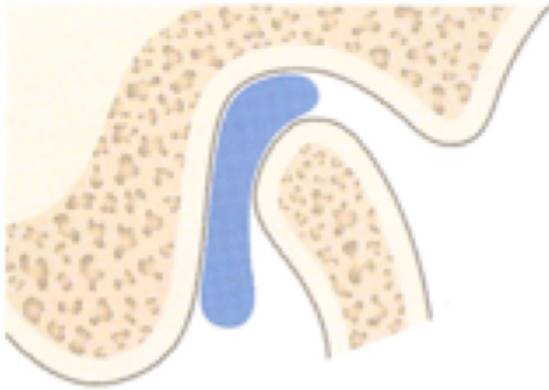
Central 41%

Disc is adjacent to fossa region

Axis
Of
Condyle
intersects

	A	B	C	D	E	F
A						
B	X	X	X			
C						
D						
E						
F						

Disc adjacent to posterior & anterior head



Normal

a

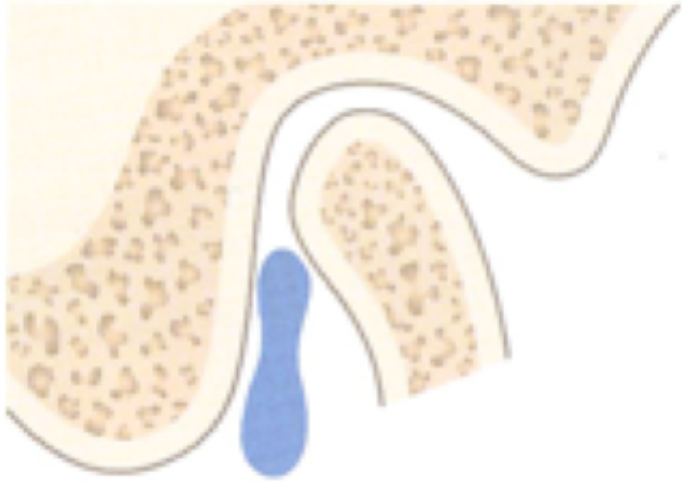
Central 41%

Disc is adjacent to fossa region

Axis
Of
Condyle
intersects

	A	B	C	D	E	F
A						
B	X	X	X			
C						
D						
E						
F						

Disc adjacent to posterior & anterior head

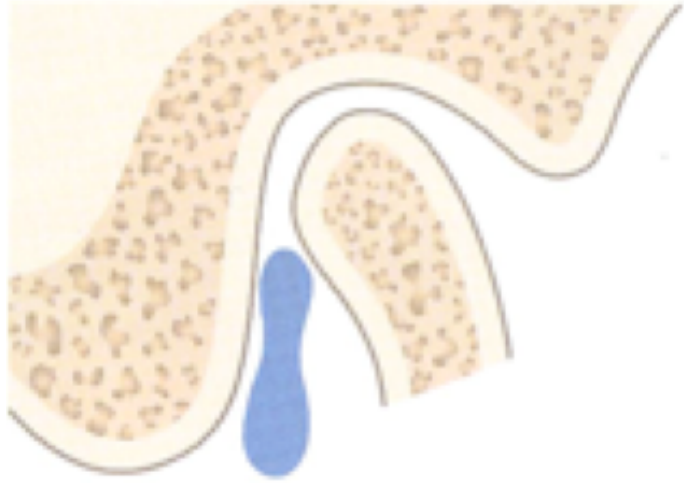


Disc is adjacent to fossa region

Axis
Of
Condyle
intersects

	A	B	C	D	E	F
A						
B	X					
C						
D						
E						
F						

Disc adjacent to anterior neck



pathological

Disc is adjacent to fossa region

Axis
Of
Condyle
intersects

	A	B	C	D	E	F
A						
B	X					
C						
D						
E						
F						

Disc adjacent to anterior neck